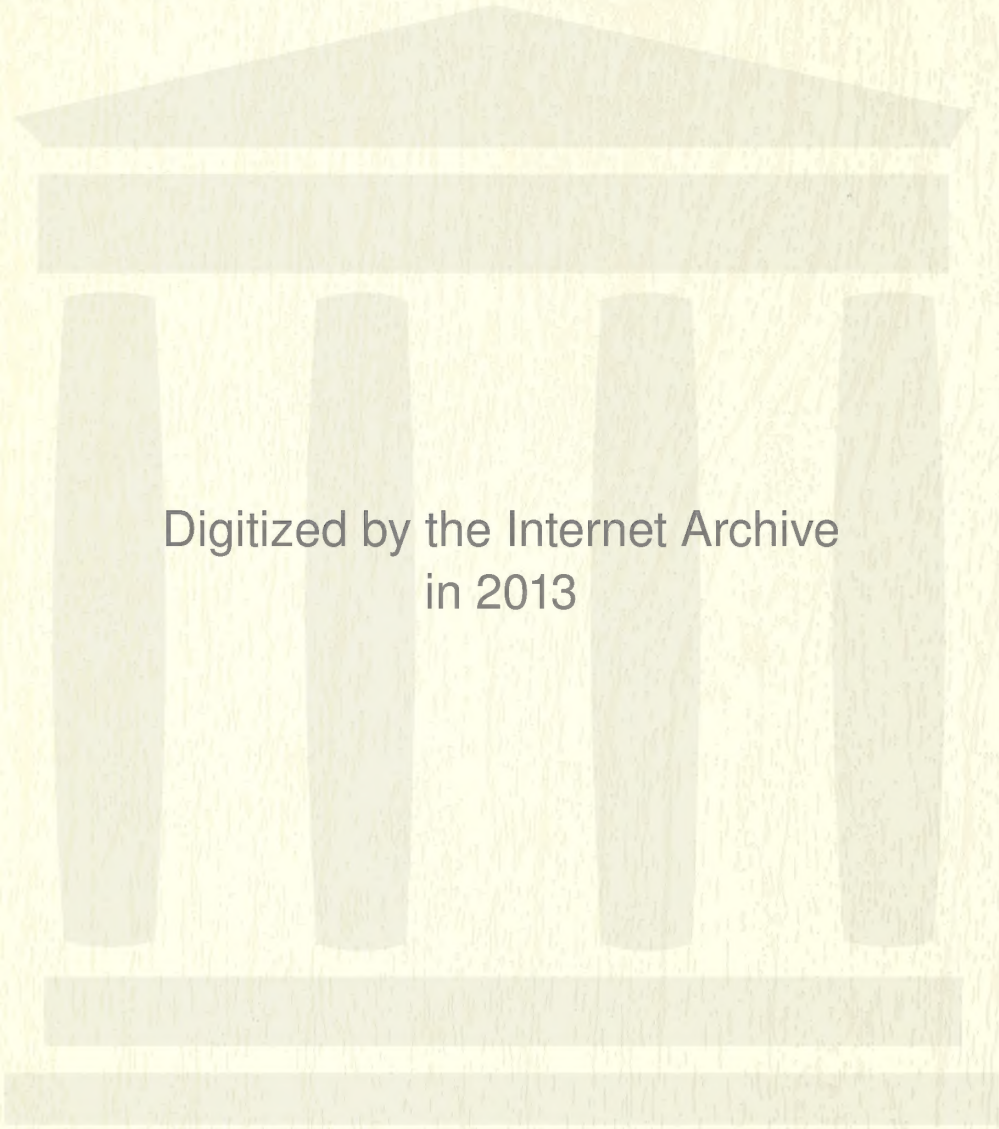




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XYLEM RESIN IN THE RESISTANCE OF THE PINACEAE TO BARK BEETLES

Richard H. Smith

Xylem resin—a supersaturation of resin acids in terpenes—appears to play a paradoxical role in the relation of the Pinaceae to tree-killing bark beetles. It has been suggested as the agent responsible for the susceptibility of this coniferous family to beetle attacks. And, at the same time, it has been linked with the ability of the Pinaceae to resist bark beetles. The hosts of tree-killing bark beetles are nearly all Pinaceae—*Pinus* (pine), *Abies* (fir), *Pseudotsuga* (Douglas-fir), *Picea* (spruce), *Tsuga* (hemlock), and *Larix* (larch). Significantly, among conifers, xylem resin is most common and abundant in these Pinaceae. Bark beetles are found on other families of conifers, but they are usually considered of minor importance.

Much experimental work has been done since the early reports of an apparent association of resin with resistance. Nearly all studies have dealt with attacking adult beetles; virtually no research has been directed at effects of resin on immature forms. Most work has been with *Pinus* and *Dendroctonus*, with lesser attention to spruce, fir, Douglas-fir, and the other genera of bark beetles.

This report summarizes the early findings, updates them with results of more recent reports and, in some cases, reinterprets these previous reports. This review deals only with bark beetles that attack living trees and with xylem resin, although in a few instances, it concerns resin-related chemicals as well.

This review follows the approach of Painter (1951), who proposed that plant resistance to insects depends on one or more

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Xylem resin of Pinaceae is closely linked with their resistance and susceptibility to tree-killing bark beetles. This review of the literature on attacking adults suggests that all three resistance mechanisms proposed by Painter—preference, antibiosis, and tolerance—are active in this relationship: preference by attraction, repellency, and synergism; antibiosis by both chemical and physical properties; tolerance by healing and secondary resinosis.

Oxford: 453-145.7X19.92 Scolytidae: 174.7 Pinaceae: U547.914.

Retrieval Terms: Pinaceae; insect-host relationships; Scolytidae; resins; terpenes; attractants; antibiosis.



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sides of a triangle—insect preference, antibiosis, and tree tolerance—and attempts to show the action of resin through these three mechanisms. Preference refers to the selection or avoidance of the plant by the insect. Painter defined antibiosis as “the tendency to prevent, injure, or destroy (insect) life.” In this discussion, the physical and chemical manifestations of resin will be considered separately. Tree tolerance, with reference to Pinaceae and bark beetles, is an active response of the tree to attack; and a brood of beetles successfully develops without killing an exteriorly noticeable part of the tree.

Stark's review (1965) was oriented somewhat along Painter's lines, but he omitted preference, and he treated antibiosis from a different viewpoint by using the classical entomological classification of stomach, contact, and fumigant toxicity. In discussing the nature of resistance, Callahan (1966) followed Painter's triangle. He proposed that the host specificity of pine bark beetles is primarily attributable to interspecific resin variation, and he rests his case largely on antibiosis.

The term allelochemicals (Wittaker and Feeny 1971) may be applied to much of the interaction of resin and beetles described herein. It is another example of the importance of secondary plant substances in insect-host relationships.

Commercially, the resin acids are called rosin; the terpenes, turpentine. Resin may also include small amounts of related alcohols and aldehydes. The terpenes are volatile hydrocarbons and are usually considered the active portion of resin in relation to bark beetle reaction.

Three main groups of terpenes are: (a) the monoterpenes, by far the most abundant in the xylem resin of most Pinaceae, which are a 10-carbon molecule and are quite volatile; (b) the sesquiterpenes, which are a 15-carbon molecule and considerably less volatile than the monoterpenes; and (c) the diterpenes, which are a 20-carbon molecule and even less volatile than the sesquiterpenes. Each of the 18 different monoterpenes has the same molecular weight and elemental composition, but different bonding or molecular configuration or both.

EFFECT OF RESIN ON BEETLE PREFERENCE

Studies to show that resin attracts or repels adult beetles have not been conclusive. Even different experiments with the same beetle and tree species have not yielded similar results. This discrepancy is not unexpected, since behavior studies are complex and difficult to interpret.

For a long time it has been known that both red (*D. valens* Lec.) and black (*D. terebrans* [Oliv.]) turpentine beetles are attracted to resin—even to fresh paint thinned with turpentine. The attractiveness of freshly cut logs to some bark beetles, notably the spruce beetle (*D. rufipennis* Kirby) and Douglas-fir beetle (*D. pseudotsugae* Hopk.), has been attributed to resin volatiles. Johnson (1966) found lightning-struck ponderosa pines were readily attacked by the western pine beetle (*D. brevicomis* Lec.). This phenomenon, which has been observed for other species of *Dendroctonus* and for several species of *Ips*, could be caused by reduced tree vigor. Since these attacks are often made immediately after the lightning strike, however, the tree's attractiveness could have been increased by the sudden release of the volatile portion of resin or their chemical derivatives, at the time of the damage to the tree.

Mirov¹ noted that in the laboratory the volatile components of ponderosa pine (*P. ponderosa* Laws.) resin both attracted and repelled western pine beetle. Gordon² was the first to show differences in the response of this beetle to terpenelike compounds in laboratory olfactometers. The difficulty of interpreting these older results may be attributed to the use of gross and impure materials. Using an improved and reliable field olfactometer and pure materials, Bedard, *et al.* (1969) found western pine beetle to be generally unresponsive to the monoterpene components of ponderosa pine resin.

McMullen and Atkins (1962) found the Douglas-fir beetle attracted to the odors of freshly cut Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). No specific component was identified. However, since freshly cut logs were much more attractive than older logs, McMullen and Atkins were apparently observing response to resin vapors. This observation was supported by Heikkinen and Hrutfiord (1965), who found that α -pinene attracted Douglas-fir beetle and β -pinene repelled it. They theorized that the α - to β -pinene ratio in Douglas-fir caused it to be attractive or repellent. Working with the same beetle and tree species, Rudinsky (1966a) reported a general ranking of attractiveness as follows: camphene > gross resin > α -pinene > limonene > four other terpenes or ter-

¹Mirov, N. T. *A preliminary study of attraction with the western pine beetle, Dendroctonus brevicomis* Lec. 1928. (Unpubl. rep. on file Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.)

²Gordon, A. *Tree injection in white fir and ecological studies of insects attacking ponderosa pine*. 1932. (Unpubl. rep. on file Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.)

penoid compounds, including β -pinene. He concluded (1966b) that "oleoresin appears to have a dual function for the Douglas-fir beetle: as an attractant orienting the beetles in flight and as a repellent. Resinosis is the most important factor in the defense mechanism of the tree."

Perttunen (1957) found that different concentrations of α -pinene changed the behavior of *Hylastes ater* and *Hylurgops palliatus*. Chararas and Deschamps (1962) speculated that resin and its volatile components of Scots pine (*P. sylvestris* L.), Norway spruce (*Picea abies* L.), and Douglas-fir were associated with host selection by *Ips typographus* L. and *I. sexdentatus* Boern. They based their case on earlier work by Chararas on bark beetle response to terpenes and on studies of the terpene composition of resin of the three coniferous species. Kangas, *et al.* (1967) found the gross extract of Scots pine phloem to be attractive to *Blastophagus piniperda* L.; they then identified the most active component as α -terpineol, an alcohol derivative of a number of monoterpenes.

Data on the synergistic action of terpenes on insect-produced pheromones continue to grow. In the early period of bark beetle attraction work, the most attractive condition was found to be feeding beetles plus the tree. The most recent work narrows the tree's contribution to individual monoterpenes from resin. Bedard, *et al.* (1969) found that myrcene, a naturally occurring terpene of pines, synergizes brevicomin, a pheromone produced by the western pine beetle; myrcene by itself was not attractive. Other studies (Pitman and Vité 1969; Vité and Pitman 1968) imply somewhat similar synergistic relationships of host terpenes and the pheromones of the mountain pine (*D. ponderosae* Hopk.), southern pine (*D. frontalis* Zimm.), and Douglas-fir beetles. Stark (1968) touches upon the possible synergistic action of host terpenes.

These advances in pheromones research and others by Pitman (1966) and Wood, *et al.* (1968) offer a new explanation about terpenes and preference. The stereochemical theory of olfaction (Amoore 1963) holds that the shape of a molecule rather than its elemental composition is responsible for the reaction of an animal to an odor. This could explain the attractiveness of natural terpenes and terpenoid compounds, since some of the terpenes are related to pheromones or are similar to them in molecular structure (Silverstein, *et al.* 1967).

The evidence for attraction or repellency has not been adequately resolved, but it is apparent that resin, particularly the terpenes, is closely aligned with host selection or avoidance. Possibly the host spe-

cificity of bark beetles is determined by the presence in resin of one or more terpenes which do or do not synergize the insect-produced pheromone. Likewise, these findings suggest new pathways in breeding for tree resistance by seeking to eliminate a natural compound which is a strong synergist to insect-produced attractants. As an example, ponderosa pines without myrcene have been found.

ANTIBIOSIS BY RESIN TO ADULT BEETLES

Antibiosis, with reference to bark beetle attack, has both physical and chemical aspects, and interaction between the two will be considered.

Physical Antibiotic Action

Some of the earliest observations on the adverse effect of resin on bark beetles suggest attribution to physical impediment; witness the term "pitch-out" and "drown-out," used to describe unsuccessful attack. At least four measures of resin flow have been devised: duration of flow, oleoresin exudation pressure (o.e.p.), oleoresin exudation flow (o.e.f.), and quantity of flow. Duration of flow is the time in days during which measurable amounts of resin flow from a standard wound; o.e.p. is pounds of pressure per square inch immediately after wounding; o.e.f. is cubic millimeters per minute immediately after wounding; quantity of flow is cubic centimeters of resin exuding over the first 24-hour period per foot of circumference from a full cross-sectional cut.

The quantity of flow as it affects beetle success was considered by Mirov³ when he measured the volume of resin flow of ponderosa pines in four areas in northeastern California. He found generally that stands with the highest average flow had less current activity by western pine beetle than stands having the lowest rate of flow.

Callaham⁴ found the duration of resin flow shorter from high-risk ponderosa pines (those most likely to be attacked and killed by bark beetles) than from low-risk trees; the predominant beetle in his study was the western pine beetle, with a much smaller incidence of Jeffrey pine beetle (*D. jeffreyi*

³Mirov, N. T. *A study of western yellow pine (Pinus ponderosa) as the host tree of Dendroctonus brevicomis*. 1928. (Unpubl. rep. on file Pacific SW. Forest and Range Exp. Stn., Berkeley, Calif.)

⁴Callaham, Robert Z. *Oleoresin production in the resistance of ponderosa pine to bark beetles*. 1955. (Unpubl. rep. on file Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.)

Hopk.), on Jeffrey pine (*P. jeffreyi* Grev. & Balf.). Callaham speculated that the quick subsidence of the flow of resin allowed the beetle to proceed unhampered with feeding and ovipositing. On the other hand, the prolonged flow from more resistant trees either exhausted, repelled, or trapped the beetle and prevented oviposition.

After one season of research on o.e.p., Vité and Wood (1961) suggested that ponderosa pines having high pressure survived bark beetle attack (primarily mountain pine beetle, with some western pine beetle) considerably more frequently than did those having low pressure. A second season of beetle attack and pressure measurements produced results of the same kind but with less difference. The stand was second-growth ponderosa pine at about 6,500 feet elevation in the central Sierra Nevada, the upper elevational limit for ponderosa pine in this area. Stark (1965) reported a similar study in which the western pine beetle was predominant, and mountain pine beetle occurred in much smaller numbers. This time little or no differential in survival was noted between trees with high and low pressure. Wood (1962), working with the California five-spined engraver (*I. confusus* Lec.) and ponderosa pine, found that trees with low and high pressure survived attack equally well. However, he did find that successful attacks became established quickest in cut logs in which the pressure dropped to zero or near zero.

Mason (1966,⁵ 1969) used the term "o.e.f." to express the initial rate of resin flow on an amount/time basis. His results suggest that the incidence of successful attack by *I. avulsus* Eichh. was greatest in loblolly pine (*P. taeda* L.) with lower o.e.f.; *I. grandicollis* Eichh., on the other hand, resembled *I. confusus* in being unable to tolerate any flow of resin. He also obtained data which suggest fairly strong gene control of o.e.f. However, there was evidence that stand and tree condition also influenced the initial rate of resin flow.

Casual observations of several pine species have attributed unsuccessful attacks of both the red and black turpentine beetle to quantity of resin flow.

Tests in which western pine beetle were forced to attack ponderosa pines were the first to show experimentally the effect of resin quantity on beetle success (Smith 1969). When the flow of resin for a 24-hour period was changed in different portions of the same tree, the success of beetle attack increased as resin

flow decreased. The number of beetles also was an important factor in determining the success of beetle attack.

Viscosity and rate of crystallization of resin are characteristics which could act as physical impediments, as Stark (1968) suggests, but experimental evidence has not been produced.

A recent study of smog-damaged ponderosa pine in the southern California mountains sought to associate a number of resin characteristics with bark beetle susceptibility (Stark, *et al.* 1968). Trees visually classified as heavily damaged by smog had, in general, lower resin pressure, lower rate of resin flow, lower total volume of flow, and higher rate of crystallization. In another part of this study, the highest percent of trees attacked by western pine beetle and mountain pine beetle was found in the heavy smog damage category. Putting the two parts of the studies together, Stark, *et al.* (1968) concluded that smog affects resin characteristics which then reduce the trees' resistance to bark beetles. It should be pointed out that the two sets of trees were not the same and that the bark beetle attacks in the second set of trees could have caused changes in the characteristics of the foliage, which are used in classifying smog damage.

Chemical Antibiotic Action

Mirov (1961) postulated that resin chemistry could be the reason for the host specificity of western pine beetle and Jeffrey pine beetle. Callaham (1966) expanded and formalized Mirov's ideas and suggested that host specificity depends on the beetle's ability to tolerate the resin of hosts and inability to tolerate the resin of nonhosts. He specifically indicated that differential toxicity is most likely in the turpentine constituents of resin.

Gordon⁶ was the first to show the terpenes and terpenelike compounds to be differentially toxic to adult western pine beetles. Smith (1963) found that resin vapors of nonhost pines were significantly more toxic than host resin vapors to the western pine, mountain pine, and Jeffrey pine beetle. Resin vapors of hybrids between host and nonhost were usually intermediate in effect, and the differences were not always significant; however, in laboratory feeding tests, these hybrid resin vapors caused a significant reduction in the feeding of adult beetles (Smith 1966a). Forced attacks under field conditions on both altered and unaltered pines generally substan-

⁵Mason, Richard R. *Dynamics of Ips populations after summer thinning in a loblolly pine plantation: with special reference to host tree resistance*. 1966. (Unpubl. Ph.D. thesis on file at Univ. Mich., Ann Arbor, Mich.)

⁶Gordon, A. *op. cit.*

tiated the laboratory results. Hybrids between host and nonhost pines were unsuitable hosts (Smith 1966b; Callaham and Miller⁷), and other tests showed that western pine beetle could attack and oviposit in cut logs of the same species and hybrids when there was no flow of resin, thus again associating resin flow with resistance.

A series of laboratory and field tests showed that the individual monoterpene components of ponderosa pine were differentially toxic to the western pine beetle (Smith 1965, 1966b, 1966c, 1969); this pine species is the primary host of the beetle. Other studies indicated a large variation among trees in a stand and among geographic regions in the monoterpene composition of ponderosa pine xylem resin. Only very slight differences in terpene composition were found within individual trees over 30 years of age (Smith 1964, 1968).

Chemical-Physical Interaction

Smith (1966) attempted to treat the interaction of chemical and physical impediment by forcing attacks of western pine beetle on ponderosa pines with different monoterpene composition. The trees were altered to change the amount of resin which flowed during different 24-hour periods. The effects of resin quality and resin quantity could then be assessed by regulating the number of attacking beetles. The results indicate that as resin flow decreases beetle success increases. But, at comparable resin flow, the degree of beetle success was markedly affected by the quality of the resin as measured by its monoterpene composition. The ranking of the monoterpene components for their effectiveness against beetle success was limonene > 3-carene > β -pinene = standard; a standard tree is one without a high concentration of any of these three terpenes. This ranking is similar to that obtained from laboratory tests of the toxic effect of individual monoterpene vapors on adult beetles (Smith 1965). Thus, the favorable effect of quality may be negated by poor quantity, as evidenced by the previously cited observation that beetles can be forced to attack and oviposit on non-resin-producing logs of nonhost species. Likewise, poor quality may be offset by good quantity.

⁷Callaham, Robert Z., and John M. Miller. *Studies of the resistance of pine hybrids to bark-beetle attacks, season of 1951. 1952.* (Unpubl. rep. on file Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.)

TREE TOLERANCE TO BEETLE ATTACK

The concept of tree tolerance is somewhat paradoxical, since bark beetles must kill all or part of a tree in order for a successful brood to develop. However, tolerance may be understood as present in those instances in which successful brood development causes no external evidence of killing or causes an active response by the tree, such as the production of different tissue or chemicals. With bark beetles, tolerance is a relative term, depending on the population density. Nevertheless, there are at least three fairly well documented cases which might be classified as tolerance.

In an early study of the fir engraver (*Scolytus ventralis* Lec.) on white fir (*Abies concolor* [Gord. & Glend.] Lindl.), Struble (1957) noted that there is often successful brood development without external evidence of injury, although a patch of dead phloem remained beneath the bark. Struble also noted that a great many attacks are not successful in producing a brood. Work by Berryman (1969, 1970) with this insect on *A. grandis* (Dougl.) shows this tree response to be a type of tolerance. Callus tissue develops to heal the wound and a secondary resin system is formed to produce a copious flow of resin which is far greater than that normally encountered. Reid, *et al.* (1967) found a somewhat similar condition with lodgepole pine (*P. contorta* Dougl. var. *latifolia* Engelm.) in response to attack by the mountain pine beetle. Callus tissue formation has been observed in species of conifers with attacks of the red and black turpentine beetle. But some uncertainty exists in these investigations about the terms "resinosis," "secondary resin," and "traumatic resin."

IMPROVING RESIN CHARACTERISTICS

Once a property of pine resin has been firmly associated with relative resistance, attempts to augment it should be considered. Merker (1967) found that irrigation and application of fertilizers increased the resistance of pine to bark beetles. He attributed this increased vigor to improved water balance. The better water balance would, in time, directly increase the production of resin. Conventional silvicultural practices, such as thinning to regulate growing stock, may indirectly improve the resin production characteristics of trees which adversely affect bark beetle attack.

Lyon⁸ suggested the possibility of introducing a chemical into the tree to increase the toxic or repel-

⁸Lyon, Robert L. Personal communication, May 1971.

lent action of the natural components of resin. The chemical could be introduced physically, or genetically, if a genetic basis could be found.

The level of the resin property might be increased through tree selection or breeding. Selection could be for both phenotypes and genotypes. Certain properties of resin—quality, synthesis, and o.e.f.—have been shown to be under strong genetic control. It is not difficult to envision the advantages of a breeding program, once the target properties have been determined.

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WILDERNESS MANAGEMENT... a computerized system for summarizing permit information

Gary H. Elsner

In summer 1971, the California and Intermountain Regions of the U.S. Forest Service began requiring permits to enter Wilderness and Primitive Areas in California. The permit system was adopted to gain additional public understanding and appreciation of wilderness areas through pre-entry contacts and to gather data useful in managing the areas. This was the first wide-scale application of such a permit requirement and as such provides resource managers and researchers with a larger data base on wilderness use than previously available.

Strong public acceptance and support¹ for the permit system was recognized at all of the 17 Wilderness Areas and the four Primitive Areas during the first summer of the program. The permits used during the first year required only a few items of information, including the name and address of party representative, number in party, area to be visited, date of visit, and point of entry and exit.

This report describes a computerized system jointly developed by U.S. Forest Service researchers and National Forest administrators to analyze these permits and to prepare summaries for wilderness management and research. All permits issued (23,936) for six of the wilderness areas were collected and used in developing and validating the system.

The Wilderness Information system is appropriate for data reduction and incorporation with planning at either the regional or national level. Although it was designed to summarize large volumes of permits, it might also be useful in smaller research or

¹The San Francisco Chronicle, January 24, 1972, p. 5.

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Permits were first needed for visits to wilderness areas in California during summer 1971. A computerized system for analyzing these permits and summarizing information from them has been developed. It produces four types of summary tables: point-of-origin of visitors; daily variation in total number of persons present; variations in group size; and variations in length of stay. The Wilderness Information system was tested by analyzing 23,936 permits issued for six California wilderness areas in summer 1971.

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Retrieval Terms: wilderness management; wilderness users; recreation use; statistics; wilderness information system.

administrative studies. The system's four computer programs are available for either the CDC 7600 or the CDC 3100.² These programs and additional information are available upon request to: Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701. Attention: Computer Sciences Librarian.

²Trade names or commercial products or enterprises are mentioned solely for information. No endorsement by the U. S. Department of Agriculture is implied.

COMPUTER PROGRAMS

The Wilderness Information system consists of four computer programs (*fig. 1*): (a) COUNTY, which converts ZIP mailing codes to origin-of-visitors indexes; (b) TOTAL, which summarizes information on total number of registered persons in a wilderness on a given day; (c) ORIGIN, which produces a summary place-of-origin table, by number of people and visitor-days; and (d) LSTAY, which produces two distribution tables: one by length of stay, the other by group

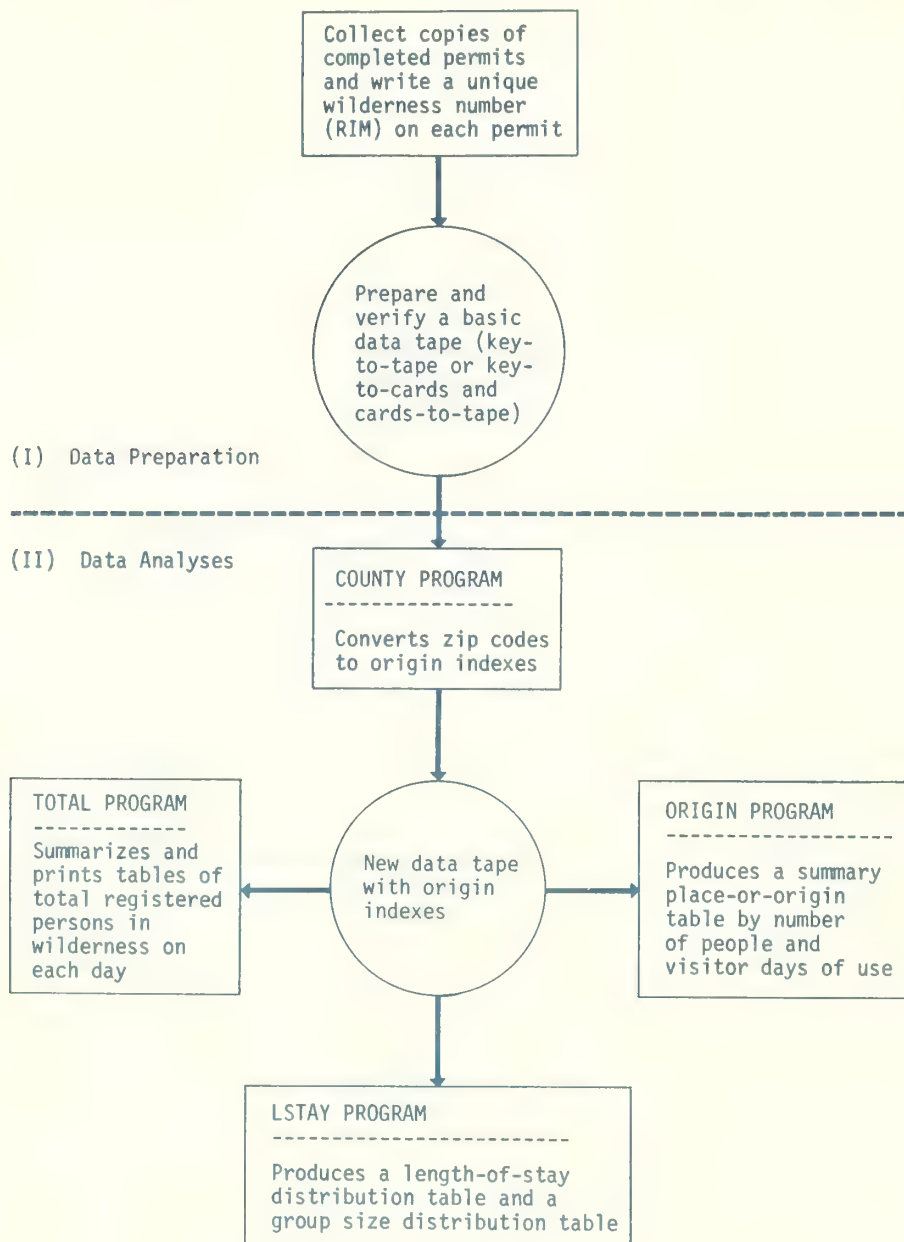


Figure 1—Work-flow in using the Wilderness Information system computer programs to summarize information from wilderness entry permits.

size. To apply these programs, the user carefully prepares the data for recording on magnetic tape, and follows the procedures set forth for each program.

The basic data used is a collection of the yellow copy of all issued permits. The Forest Service's California Region, headquartered in San Francisco, included a white copy for the visitor, a pink copy for the Ranger District where the trip started, and the yellow copy for the Regional Office and Experiment Station. Careful planning was necessary to inform issuing agents to forward the yellow copy of all completed forms to the Regional Office.

Since the data bank will often contain thousands of permits it may be most convenient to have the tape prepared directly and thus avoid several intermediate steps. If equipment is not available for the key-to-tape operation, then computer cards can be punched with the information and a tape prepared from these cards. The programs are designed so that the basic data tape need not be grouped or sorted according to either wilderness or date, but each record must contain a unique identifying number for the wilderness. The length and structure of this basic record can be modified by changing only one subroutine in the system.

This basic data tape is then processed with the COUNTY program and a new tape is made which has ZIP codes replaced with origin indexes. The origin index indicates the visitors' county of residence if he came from California, Arizona, Nevada or Oregon. Otherwise the origin index identifies the state of residence. The COUNTY programs are essentially the same as those used for campground registration analysis (Elsner 1971). But the Wilderness Information System programs are designed for the CDC 3100 and the CDC 7600 instead of the UNIVAC 1108 computer so that they can be easily implemented in other Regions of the Forest Service.

SUMMARIZED INFORMATION

The tape is used in preparing any of these four tables of summarized information: (1) origin of visitors, (2) persons present on each day; (3) length of stay variation; and (4) group size variation.

The three sets of programs used in producing the four tables are ORIGIN, TOTAL, and LSTAY. Each table is based upon all permits in the data bank that has the information relevant to that particular table. For example, if a permit has the ZIP code missing but all other data complete, then it will be used in preparing all tables except the point-of-origin table.

The information presented in the origin-of-visitors table basically delineates the market area which the

wilderness serves. For example, we found that about 14 percent of the use at Desolation Wilderness was by residents of the closest county, El Dorado, in summer 1971 (*fig. 2*). Also we found that 12 percent of the use came from Sacramento County, 10 percent from Santa Clara County, 10 percent from Alameda County, and 7 percent from San Mateo County. Altogether, those five counties contributed more than 53 percent of the use. By adding all the items in column 5 for "other states" it was easy to determine that slightly more than 2 percent of the use came from Nevada, 0.81 percent from Oregon, 0.01 percent from Arizona, and more than 95 percent from California.

This type of information, whether in tabular or graphical form, has already seen extensive use by wilderness managers and planners from assisting in defining the general nature of the population market the resource serves to providing a basis for the selection of public meeting locations. Research personnel are using these data to develop methods for predicting use at existing and proposed wilderness areas.

The second table which the system can prepare - persons with permits present on each day - may be of even greater interest to resource managers. It provides data necessary to have a quantitative understanding of total human use of the wilderness and the daily distribution of use throughout the season (*fig. 3*).

Because the peak-use periods are often an environmental concern, it is well to identify these periods in the planning process. For example, Desolation Wilderness had 2,888 permitted visitors on August 8, 1971. Although the peak-use days in the next years may not be identical, these data will provide an estimate of the periods requiring intensive management.

The last two tables on length-of-stay variation (*fig. 4*) and group-size variation (*fig. 5*) provide further information for site management and for an understanding of the type of use the wilderness is receiving. The statistics on such items as average stay per visit differ quite significantly from one wilderness to the next. For example, the average stay per visit of 5.6 visitor-days for Desolation Wilderness contrasts with the average stay per visit of 9.9 visitor-days at Marble Mountain Wilderness in northern California. Of six wilderness areas studied, the shortest average stay per visit was recorded at the San Jacinto Wilderness in southern California. These data and other analyses indicate that distance traveled to wilderness areas and length of stay are closely correlated.

The average group size visiting the Desolation Wilderness was observed to be four persons. This contrasts significantly with an average group size of 2.3

ORIGIN OF VISITORS
DESOLATION 1971

ORIGIN	NUMBER OF PERMITS	NUMBER OF PEOPLE	PERCENT OF TOTAL PEOPLE	AMOUNT OF USE (V/D)	PERCENT OF TOTAL USE
CALIFORNIA COUNTIES					
ALAMEDA	902	3382	10.88	18155	9.81
ALPINE	1	2	.01	2	.00
AMADOR	5	19	.06	1457	.79
BUTTE	21	52	.17	433	.23
CALAVERAS	1	2	.01	4	.00
COLUSA	8	24	.08	56	.03
CONTRA COSTA	647	2800	9.01	17231	9.31
EL DORADO	882	4192	13.48	25777	13.93
FRESNO	18	55	.18	469	.25
GLENN	1	6	.02	120	.06
HUMBOLDT	8	27	.09	70	.04
IMPERIAL	2	6	.02	120	.06
INYO	4	17	.05	85	.05
KERN	17	56	.18	368	.20
KINGS	3	6	.02	28	.02
LAKE	3	10	.03	54	.03
LOS ANGELES	392	1309	4.21	10371	5.61
MADERA	4	15	.05	105	.06
MARIN	332	1312	4.22	9026	4.88
MENDOCINO	6	18	.06	374	.20
MERCED	4	27	.09	33	.02
MONTEREY	26	87	.28	258	.14
NAPA	46	185	.60	944	.51
NEVADA	25	154	.50	784	.42
ORANGE	85	268	.86	1478	.80
PLACER	194	816	2.62	5210	2.82
PLUMAS	3	19	.06	152	.08
RIVERSIDE	18	64	.21	412	.22
SACRAMENTO	1067	4936	15.88	23177	12.53
SAN BENITO	3	10	.03	17	.01
SAN BERNARDINO	22	79	.25	841	.45
SAN DIEGO	52	148	.48	872	.47
SAN FRANCISCO	522	1778	5.72	11580	6.26
SAN JOAQUIN	92	449	1.44	2427	1.31
SAN LUIS OBISPO	8	16	.05	237	.13
SAN MATEO	490	1979	6.37	13818	7.47
SANTA BARBARA	20	59	.19	194	.10
SANTA CLARA	694	2967	9.54	18259	9.87
SANTA CRUZ	45	160	.51	1058	.57
SHASTA	3	7	.02	18	.01
SISKIYOU	1	4	.01	4	.00
SOLANO	74	307	.99	1117	.60
SONOMA	104	438	1.41	3653	1.97
STANISLAUS	38	173	.56	942	.51
SUTTER	10	37	.12	114	.06
TEHAMA	4	16	.05	204	.11
TULARE	4	22	.07	138	.07
TUOLUMNE	4	27	.09	154	.08
VENTURA	34	116	.37	735	.40
YOLO	215	903	2.90	3185	1.72
YUBA	9	20	.06	89	.05

Figure 2—Example of an "Origin of Visitors" table that can be produced by the ORIGIN computer programs. The table is for the Desolation Wilderness, California, summer 1971.

ORIGIN	NUMBER OF PERMITS	NUMBER OF PEOPLE	PERCENT OF TOTAL PEOPLE	AMOUNT OF USE (V/D)	PERCENT OF TOTAL USE
NEVADA COUNTIES					
CHURCHILL	7	98	.32	228	.12
CLARK	5	12	.04	56	.03
DOUGLAS	49	147	.47	668	.36
LYON	1	3	.01	120	.06
MINERAL	1	2	.01	4	.00
ORMSBY	16	45	.14	146	.08
WASHOE	128	473	1.52	2091	1.13
OREGON COUNTIES					
BENTON	3	9	.03	32	.02
CLACKAMAS	1	2	.01	4	.00
DESCHUTES	1	4	.01	16	.01
DOUGLAS	1	35	.11	770	.42
LANE	4	9	.03	66	.04
MARION	1	2	.01	4	.00
MULTNOMAH	7	37	.12	586	.32
WASCO	1	2	.01	2	.00
ARIZONA COUNTIES					
MARICOPA	5	8	.03	22	.01
OTHER STATES					
ARIZONA	6	13	.04	74	.04
COLORADO	9	26	.08	168	.09
DISTRICT OF COLUMBIA	12	31	.10	162	.09
FLORIDA	9	32	.10	245	.13
GEORGIA	1	1	.00	12	.01
HAWAII	3	11	.04	14	.01
IDAHO	1	2	.01	4	.00
ILLINOIS	30	79	.25	490	.26
INDIANA	8	24	.08	73	.04
IOWA	4	10	.03	38	.02
KANSAS	4	12	.04	24	.01
KENTUCKY	1	2	.01	8	.00
LOUISIANA	2	3	.01	70	.04
MARYLAND	4	14	.05	31	.02
MINNESOTA	9	28	.09	55	.03
MISSOURI	5	16	.05	98	.05
NEW MEXICO	3	6	.02	18	.01
NEW YORK	45	106	.34	1013	.55
NORTH CAROLINA	3	4	.01	16	.01
OHIO	9	23	.07	79	.04
OKLAHOMA	2	7	.02	46	.02
PENNSYLVANIA	9	24	.08	54	.03
TENNESSEE	1	3	.01	6	.00
TEXAS	15	41	.13	295	.16
UTAH	4	9	.03	30	.02
VIRGINIA	3	9	.03	131	.07
WASHINGTON	24	53	.17	332	.18
WISCONSIN	7	15	.05	142	.08
WYOMING	2	16	.05	72	.04
TOTAL	7639	31089	100.00	185024	100.00

PERMITS WITH VALID GROUP SIZE AND STAY INFORMATION 7608
 PERMITS WITH MISSING OR INVALID ZIP CODE 268
 TOTAL PERMITS CONSIDERED 7975

Figure 2—Cont'd

PERSONS PRESENT ON EACH DAY DESOLATION 1971													
		MONTH											
		1	2	3	4	5	6	7	8	9	10	11	12
D	1	1	2	1	2	2	2	658	2103	1242	126	3	0
A	2	1	1	1	2	2	2	1131	1800	1288	238	2	0
Y	3	1	1	1	2	2	2	1984	1877	1481	220	2	0
	4	1	1	1	2	2	10	2272	2051	2144	122	2	0
	5	1	1	1	2	2	20	2018	2093	2229	119	2	0
	6	1	1	1	2	2	15	1165	2181	1768	127	2	0
	7	1	1	1	2	2	6	1140	2639	901	117	2	0
	8	1	1	1	2	2	10	1191	2888	733	196	2	0
	9	1	1	1	2	2	10	1411	2263	730	283	2	0
	10	1	1	1	2	2	12	1966	1977	794	272	2	0
	11	1	1	1	2	2	12	1872	2043	890	159	0	0
	12	1	1	1	2	2	22	1206	2214	786	48	0	0
	13	1	1	1	2	2	22	1294	2265	728	43	0	0
	14	1	1	1	2	2	25	1516	2593	308	47	0	0
	15	1	1	1	2	2	26	1519	2434	336	60	0	0
	16	1	1	1	2	2	23	1729	1761	344	128	0	0
	17	1	1	1	2	2	37	2074	1891	496	151	0	0
	18	1	1	1	2	2	42	1945	1960	697	55	0	0
	19	1	1	1	2	2	84	1316	2020	676	44	0	0
	20	1	1	1	2	3	93	1391	2167	364	44	0	0
	21	1	1	1	2	2	93	1424	2393	285	27	0	0
	22	1	1	1	2	2	116	1370	2185	233	30	0	0
	23	1	1	1	2	2	135	1565	1967	234	96	0	0
	24	1	1	1	2	2	183	2083	1952	335	84	0	0
	25	1	1	1	2	2	452	2032	1991	451	75	0	0
	26	1	1	1	2	2	740	1553	1940	389	20	0	0
	27	1	1	1	2	2	770	1586	1932	183	20	0	0
	28	1	1	1	2	2	508	1656	2067	154	20	0	0
	29	1	1	1	2	2	508	1764	1770	147	20	0	0
	30	1	1	1	2	2	552	1901	1420	127	20	0	0
	31	1	1	1	2	2	2271	1277			5		1

7939 PERMITS USED IN ABOVE TABLE

36 NOT USED BECAUSE OF INSUFFICIENT INFORMATION

Figure 3—Example of a "Persons Present on Each Day" table that can be produced by the TOTAL programs.

LENGTH OF STAY VARIATION DESOLATION 1971				
LENGTH OF STAY (VISITOR DAYS)*	NUMBER OF PERMITS	NUMBER OF PEOPLE	PERCENT OF TOTAL PEOPLE	CUMULATIVE PERCENT OF TOTAL PEOPLE
1	1435	5731	18.0	18.0
2	1078	12774	40.1	58.1
3-4	932	3451	10.8	69.0
5-6	605	2320	7.3	76.3
7-8	342	1189	3.7	80.0
9-10	249	1148	3.6	83.6
11-12	447	2191	6.9	90.5
13-14	160	852	2.7	93.2
15-16	96	339	1.1	94.2
17-18	66	218	.7	94.9
19-20	37	109	.3	95.2
21-22	30	128	.4	95.6
23-24	30	107	.3	96.0
25-26	109	360	1.1	97.1
27-28	31	118	.4	97.5
29-30	17	85	.3	97.8
31-32	14	51	.2	97.9
33-34	16	60	.2	98.1
35-36	8	26	.1	98.2
37-38	12	62	.2	98.4
39-40	14	33	.1	98.5
41-42	9	25	.1	98.6
43-44	8	20	.1	98.6
45-46	8	24	.1	98.7
47-48	6	18	.1	98.8
49-50	3	31	.1	98.9
OVER 50	110	366	1.1	100.0
TOTAL	7872	31470	100.0	100.0

AVERAGE STAY PER VISIT = 5.7 VISITOR DAYS
AVERAGE STAY PER GROUP = 23.2 VISITOR DAYS

PERMITS USED IN ABOVE TABLE = 7872
PERMITS NOT USED BECAUSE GROUP SIZE MISSING = 72
PERMITS NOT USED BECAUSE STAY INFORMATION MISSING = 31

*A VISITOR DAY EQUALS 12 VISITOR HOURS

Figure 4—Example of a "Length of Stay Variation" table that can be produced by the LSTAY programs.

Figure 5—Example of a "Group Size Variation" table that can be produced by the LSTAY programs.

GROUP SIZE (NUMBER OF PEOPLE)	NUMBER OF GROUPS	PERCENT OF TOTAL GROUPS	CUMULATIVE PERCENT OF TOTAL GROUPS
1	646	8.6	8.6
2	2905	38.4	45.1
3	1216	15.4	60.6
4	1220	15.6	76.2
5	508	7.2	83.4
6	424	5.4	88.8
7	180	2.3	91.0
8	152	1.9	93.0
9	73	.9	93.9
10	64	1.1	95.0
11- 15	152	1.9	97.0
16- 20	149	1.9	98.9
21- 25	47	.6	99.5
26- 30	23	.3	99.7
31- 35	7	.1	99.8
36- 40	8	.1	99.9
41- 45	1	.0	99.9
46- 50	2	.0	100.0
51- 75	2	.0	100.0
76-100	0	0.	100.0
101-125	0	0.	100.0
126-150	0	0.	100.0
151-175	0	0.	100.0
176-200	0	0.	100.0
OVER 200	0	0.	100.0
TOTAL	7872	100.0	100.0
AVERAGE GROUP SIZE = 4.0 PEOPLE			
PERMITS USED IN ABOVE TABLE = 7903			
PERMITS NOT USED BECAUSE GROUP SIZE MISSING = 72			

persons for the Ventana Wilderness which is located about halfway between San Francisco and Los Angeles on the Pacific Coast and 6.5 persons for the San Geronio Wilderness which is only about 1-hour's driving time east of Los Angeles. The median (or most frequent) group size was 2.0 for each of the six Wilderness Areas studied.

COMPARISON TABLES

Tables can be prepared for each wilderness separately and selected information can be quickly combined for the preparation of comparison tables (*table 1*). Data shown in the table on average stay, average group size, and peak usage are based upon *all* permits issued for six wilderness areas during summer 1971.

Table 1—Selected information from computer-generated summary tables for six California wilderness areas

Wilderness	Total registered visitors	Average stay (days)	Average group size	Highest use day	
				Visitors	Day (1971)
Desolation	31,470	2.8	4.0	2,888	Aug. 8
San Jacinto	17,180	1.1	5.0	1,439	June 26
Ventana	9,759	2.5	2.3	773	July 4
Marble Mountain	4,879	5	4.4	608	July 4
San Geronio	31,167	1.1	6.5	2,636	July 17
Emigrant	6,276	5	4.3	1,424	Aug. 14

As such, they are probably highly reliable estimates. The first column on total registered visitors is similarly derived from the total collection of permits. If the percent of visitors who obtained permits varies across wilderness areas, then the final estimates of total usage may have slightly different relationships than that shown in this first column.

The complete set of tables for the six wilderness areas studied—Desolation, San Jacinto, Ventana, Marble, San Geronio, Emigrant—are available from this Station upon request.

When the system is used to summarize a total collection of permits issued for a wilderness area, the data will not only be quite reliable, but will provide a sound basis for studying alternative sampling designs for future analyses.

Acknowledgments: An initial list of useful and needed items on wilderness management information was prepared by Warren Walters of the Division of Recreation, California Region, U.S. Forest Service, San Francisco, California. Discussion with Carl Westrate, also with the Division of Recreation, resulted in an over-all design of the computerized system. Michael R. Travis, of the Pacific Southwest Forest and Range Experiment Station, was responsible for most of the development, validation, and trial implementation of the system.

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EDITOR'S NOTE: *General Technical Report* is a new series of Forest Service research publications that complements the three existing series: *Research Paper*, *Research Note*, and *Resource Bulletin*. The General Technical Report series serves as an outlet for information of a technical nature but not necessarily the product of a specific piece of original research or resource survey.

DECLINE OF OHIA LEHUA FORESTS IN HAWAII

Robert E. Burgan Robert E. Nelson



On the island of Hawaii, thousands of acres of ohia lehua (*Metrosideros collina*) forests have died, and tree death is progressing rapidly into healthy forests. Ohia trees are the chief victims, but koa (*Acacia koa*) trees are also dying. Covering some 600,000 acres on the island of Hawaii, ohia and koa forests provide a variety of resource values—watershed cover, wildlife habitat, timber, forage, and recreation. Some parts are still relatively undisturbed and, therefore, are of special significance for scientific study. Furthermore, these forests are unique, having evolved in isolation from other forests. Ways to prevent an epidemic situation from spreading further must be given intensive and immediate study. Unless a remedy can be found, ohia forests as known today may become relicts.

Most of the affected area is on State-owned land, but significant acreage of National Park and private lands are also included. The decline of the ohia forests is of concern to a number of agencies:

- The County of Hawaii Department of Water Supply is concerned that one result may be a decline in the quality or quantity of water flowing from mountain watersheds.
- The Volcanoes National Park has reported that most of a 9,000-acre section of the Upper Olaa Forest Reserve is affected. This Reserve was set aside in 1951 because it was such a good example of the original forest and vegetation type on the island.
- The U.S. Fish and Wildlife Service has noted that within the National Park, both the number of bird species and total bird populations are rapidly declining in areas where the ohia forest has died, in contrast to no change or growth in populations where the trees are still healthy.

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USDA FOREST SERVICE
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Burgan, Robert E., and Robert E. Nelson

1972. **Decline of ohia lehua forests in Hawaii.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 4 p., illus. (USDA Forest Serv. Gen. Tech. Rep. PSW-3)

Thousands of acres of ohia lehua (*Metrosideros collina*) forests on the island of Hawaii have died, and tree death is progressing rapidly into healthy forests. Most of the losses are on State-owned lands. All of the "ohia decline" cannot be attributed to the same agent. Some of the earlier decline was attributed to frost and sulphur dioxide. But other factors, including possibly the shoestring root-rot (*Armillaria mellea*), are responsible for the current losses. Federal and State agencies are seeking to determine the causes of the decline and what control measures are feasible.

Oxford: 48(969) [+ 176.1 *Metrosideros collina* + 176.1 *Acacia koa* + 172.8 *Armillaria mellea*].

Retrieval Terms: Hawaii; ohia decline; forest diseases; epidemics; *Acacia koa*; *Metrosideros collina*; *Armillaria mellea*.



The ohia forest at the right appears healthy compared to that at the left. Whether the "disease front" is moving into the healthy forest is not known.

near Pauahi and Hiiaka Craters in a 1946 report about insect conditions in Hawaii National Park.¹ But only recently has the "ohia decline" on the island of Hawaii reached epidemic proportions.

All of the "ohia decline" cannot be attributed to the same agent. Several small pockets of ohia above 4,000 feet elevation have been either damaged or killed down to ground line by frost. In areas near volcanoes, some trees have been injured by poisonous fumes, chiefly sulphur dioxide. Most of the current loss, however, is not likely due to either frost or sulphur dioxide.

SHOESTRING ROOT-ROT

An apparent contributing factor is shoestring root-rot (*Armillaria mellea*). This root-destroying fungus has been isolated from affected trees in areas of serious decline where sulphur dioxide and frost are definitely not involved. The fungus was first reported attacking forest trees in Hawaii by Robert V. Bega, of the U.S. Forest Service, who discovered it on silk-oak (*Grevillea robusta*) in 1962. It was subsequently found on koa and ohia by Raabe in 1963 (Raabe and Trujillo 1963).

Since then the fungus has been observed by others on these same species. It has also been found on haukuahiwi (*Hibiscadelphus hualalaiensis*), naio (*Myoporum sandwicense*), olupua (*Osmanthus sandwicense*), kopiko (*Straussia* sp.), manono (*Gouldia* spp.), pilo (*Coprosma* spp.), kolea (*Myrsine* spp.), mamaki (*Pipturus albidus*), a'e (*Zanthoxylum dipetalum*), pukiaawe (*Styphelia tameiameiae*), and mamani (*Sophora chrysophylla*).²

Armillaria mellea may have been introduced into the Hawaiian Islands on fruit tree nursery stock during the early 1900's. Its subsequent spread could have been accelerated by the high populations of introduced rats and wild pigs.

This fungus is propagated in two ways: Its basidiospores are wind-borne and can establish themselves in old stumps or dead trees, but cannot infect healthy

● The U.S. Forest Service and Hawaii Division of Forestry estimate that the ohia and koa forests hold a total volume of about 470 million board feet of timber. At a stumpage value of only \$10 per 1,000 board feet, for example, this resource would be worth nearly \$5 million on the stump—a base for some \$125 million worth of consumer products. Probably 10 percent of the timber has already been killed in the epidemic.

"OHIA DECLINE"

Published reports of the decline of ohia forests date from 1909, when Lyon (1909) told about forests dying on windward Maui. Clifton J. Davis, Entomology Branch Chief, Hawaii Department of Agriculture, referred to the "Ohia Lehua Dieback"

¹Notes on Forest Insect Conditions, Hawaii National Park for the year 1946. January 6, 1946. (Memorandum on file at the Institute of Pacific Islands Forestry, Honolulu, Hawaii.)

²Communication with Franklin Laemmlen, Plant Pathologist, University of Hawaii, and observations of the U.S. Forest Service and Hawaii Division of Forestry Survey Team.



This heavily diseased portion of an ohia forest is typical of thousands of acres of forest decline on the island of Hawaii.



Only the skeletal stems of trees remain in what was once a luxuriant ohia rain forest on the island of Hawaii.

trees. Healthy trees are infected by the brown or black cordlike rhizomorphs or "shoestrings" which grow out from infected roots. On meeting a healthy root, the rhizomorph penetrates it and grows up the cambial layer to the root crown, which it girdles. The leaves become dwarfed, turn yellow or fall prematurely; on small trees all foliage may die simultaneously.

The parent lava type, soil structure, moisture stresses, insects, and other ecological factors may also be involved in the decline.

HILO FOREST RESERVE

The condition of the ohia forest within the boundaries of the 120,000-acre Hilo Forest Reserve, has been evaluated on a sampling basis from black and

white aerial photographs taken in 1954 and 1965. The area in each of four condition classes was estimated. The four classes were: (1) healthy forest—no trees dead; (2) slight decline—less than 20 percent of trees dead; (3) moderate decline—20 to 60 percent of the trees dead; (4) severe decline—more than 60 percent of the trees dead.

The area of healthy forest decreased from 53,000 acres in 1954 to 43,000 acres in 1965. The acreage of slight and moderate decline remained about the same. But the area of severe decline nearly tripled—from 5,000 acres in 1954 to 14,000 acres in 1965.

Observations indicate that the present decline condition is even more serious. Large areas of forests observed as healthy in 1967 are now heavily affected as the decline has spread rapidly south from the Saddle Road.

What can be done about this situation? The U.S. Forest Service, Hawaii Division of Forestry, University of Hawaii, Hawaii Department of Agriculture,

and U.S. National Park Service have joined forces in seeking answers to such questions as: What is the present location, extent, and rate of spread of the epidemic? What are the subsequent effects on the composition of the forests? What are the major causes of death of the ohia and koa trees? What are the factors (host-pathogen-environment complexes) contributing to the recent acceleration of this decline? Can feasible control measures be developed and if not, what are the alternatives? Deciding on alternates if practical control measures are not possible may well be the most challenging task in this coordinated effort.

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Hawaii Department of Land and Natural Resources

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FOREST FIRE HISTORY...

a computer method of data analysis

Romain M. Mees

In the continuing effort to control forest fires, the information gathered on the Individual Fire Reports (U.S. Forest Service Form 5100-29) is of great potential value. Its usefulness as a basis for control planning and for future research and development depends, however, on the degree to which it can be quickly summarized and clearly presented.

The data from these Reports for past years on a given National Forest, though not necessarily representative of current conditions, do provide some insight into potential problems. And they establish a basis for estimating probabilities of fire occurrence, detection time, initial attack time, and other related variables.

This report describes a series of digital computer programs designed to retrieve and present information from the Individual Fire Reports. Copies of the programs and a description of their mathematical derivation are available, upon request, from the Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

The programs are written in Fortran for operation on the IBM 360 computer. Two programs read and summarize data—one on fire occurrence and the other on fire detection and initial attack time. They are used in conjunction with a third program that computes the sample distribution and attempts to fit the data with a series of known continuous distributions. In the following description of the programs, sample distributions have been computed to illustrate the program output. Data used in the illustrations are drawn from several National Forests: the San Bernardino, Angeles, and Cleveland in California; the Clearwater in Idaho; and the Deschutes in Oregon.

PACIFIC SOUTHWEST Forest and Range Experiment Station

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ARTMENT OF AGRICULTURE
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USDA FOREST SERVICE
GENERAL TECHNICAL
REPORT PSW-4 /1972

Mees, Romain M.

1973. *Forest fire history...a computer method of data analysis*. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 7 p., illus. (USDA Forest Serv. Gen. Tech. Rep. PSW-4)

A series of computer programs is available to extract information from the Individual Fire Reports (U.S. Forest Service Form 5100-29). The programs use a statistical technique to fit a continuous distribution to a set of sampled data. The goodness-of-fit program is applicable to data other than the fire history. Data summaries illustrate analysis of fire occurrence, detection and initial attack time, and space and time relationships of multiple fires.

Oxford: 432.38-015.5:431.6-015.5:U681.3.

Retrieval Terms: lightning fires; fire occurrence; fire distribution; fire suppression; statistical analysis; computer programs.



FIRE OCCURRENCE PROGRAM

The fire occurrence program summarizes data on the number and size of fires and on the distribution of fires in time and space. By using this program, a cumulative sample distribution of fire occurrences over the 1960-69 period, projected on a 1-year time base, was produced for the San Bernardino and Clearwater National Forests (*fig. 1*). The analysis shows that on the Clearwater 95 percent of the 1,056 lightning-caused fires occurred in a 3-month period. There were more man-caused fires on the San Bernardino National Forest, and they occurred throughout the year.

The cumulative lightning fire occurrence curves for both Forests are smooth S-shaped curves. Lightning-caused fires (a natural process) are seen to be normally distributed. For example, for the Clearwater National Forest, the mean, with respect to elapsed time

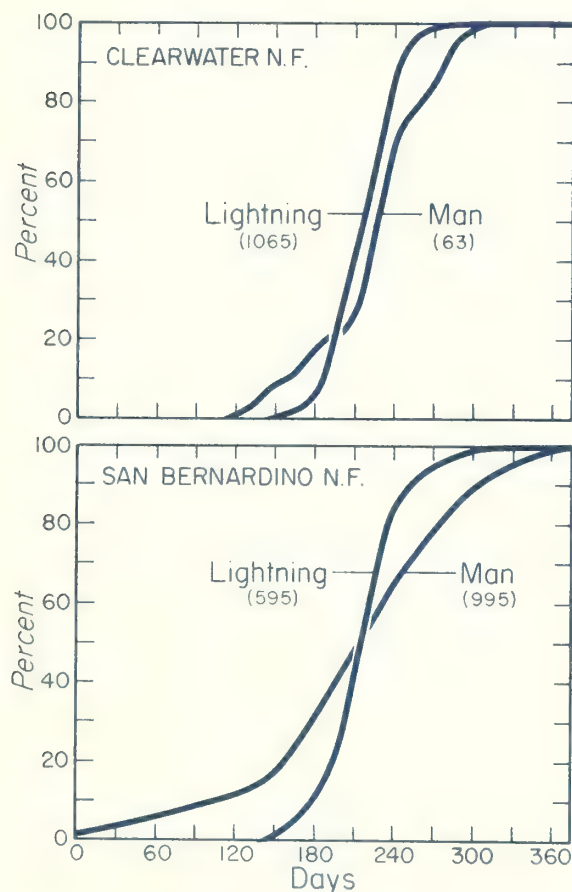


Figure 1—Sample distribution of man-caused and lightning fires, Clearwater National Forest, Idaho, and San Bernardino National Forest, California, 1960-69, projected over a 1-year period.

from the beginning of the year, is about the 216th day, with a standard deviation of 24 days.

Man-caused fires are less easily predictable, and the methods presented here may or may not be applicable—depending on local conditions.

The data on fire size yield a useful comparison, based on reports from four National Forests (*table 1*).

Table 1—Acreage burned in fires from all causes, on four National Forests, 1960-1969

National Forest and State	Total fires	Total acres burned	Total fires 0.25 acres or more	Fires burning 10,000 acres or more	
				Number	Acres burned
Cleveland (Calif.)	574	91,532	161	1	48,639
Angeles (Calif.)	774	215,000	262	6	146,332
San Bernardino (Calif.)	1,590	95,800	253	3	55,742
Clearwater (Idaho)	1,118	13,700	142	0	0

During the 90-day lightning season on the Clearwater National Forest, a large number of lightning-caused fires occur, with frequent multiple occurrences on a given day. The program yields the cumulative probability of this event, given that at least one lightning fire will occur:

<u>Fires per day</u>	<u>Cumulative probability</u>
1	0.48
2	.63
3	.70
4	.78
5	.81
6	.84
8	.89
10	.91
25	.996
36	1.00

All lightning fire occurrences during a given year may be set in increasing order of time while account is taken of the location of each one. During a single storm, lightning fire starts may cluster about an *initial* occurrence, which is defined according to specific time and space limits. An initial occurrence is a lightning fire start that (a) is outside a given radius measured from the location of a previous initial fire, (b) beyond a given maximum time span measured from the same previous initial fire, and (c) followed by one

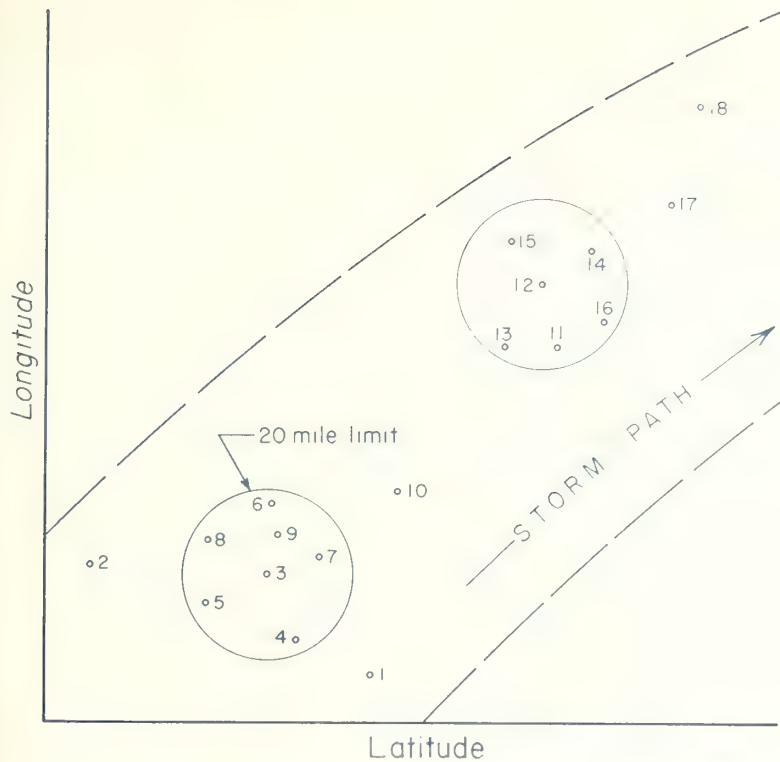


Figure 2—A series of lightning fire starts caused by a hypothetical storm. Fire starts are numbered in order of time. Circled fires are multiple fires related to the earliest start in each circle; fires 9 and 11 are exceptions outside the required time limit of 3 hours.

or more fire starts, all of which are within the given distance and time limits.

For example, in the storm pattern shown in *figure 2*, the limits were set at 3 hours and 20 miles from an initial lightning occurrence. Here 18 lightning fire starts were observed at times indicated by their numerical order. Fires 1 and 2 were single occurrences; no other fires occurred within the required limits. Fire 3 was followed by 4, 5, 6, 7, and 8 within the time and distance limits. Fires 9, 10, and 11 were single occurrences. Initial fire 12 was followed by four fires within the required limits. Although fires 9 and 11 were within the required radial distance of fires 3 and 12, respectively, they were not within the required time limit of 3 hours.

The computer program by which this summary is produced identifies the initial fires and prints their location and time of discovery, the number and length of multiple occurrences, and the distance and time from each multiple lightning fire to its initial fire.

A useful tool in decision-making is an estimate of the probability of multiple lightning fire starts with respect to time and distance. The following set of cumulative sample distributions is based on the years 1960 through 1969 for the Deschutes National Forest. From these curves it is possible to reconstruct the past 10 years of lightning fire history and to at-

tempt some predictive statements. Furthermore, by sampling on a uniform 0 to 1 interval, it is possible to simulate the past 10 years and use the output in other computer models for which estimates of the location and frequency of lightning fires are needed.

First, the cumulative distribution of the number of multiple fire starts is given in *figure 3*. The curve indicates, for example, that given an initial fire start, the probability of an additional two or three fire starts within 20 miles and 6 hours is about 10 percent.

Next, the 346 multiple fires were uniformly spread within a 20-mile radius of their initial fire starts (*fig. 3*).

The distribution curve for multiple lightning fire starts (*fig. 3*) shows the distribution of the same 346 fires within the 6-hour limit.

The cumulative distribution curves for latitude, longitude, and time of year for the initial fire starts (*fig. 4*) may clarify the role of these variables in lightning fires.

Starting with the curves from *figure 4*, it is possible to select the location and time of an initial fire start and use *figure 3* to find the number of multiple fire starts associated with it. Finally, *figure 3* can also be used to determine the time and distance relation of each multiple fire to its initial fire. This procedure, applied to data from a specific area, may be of value

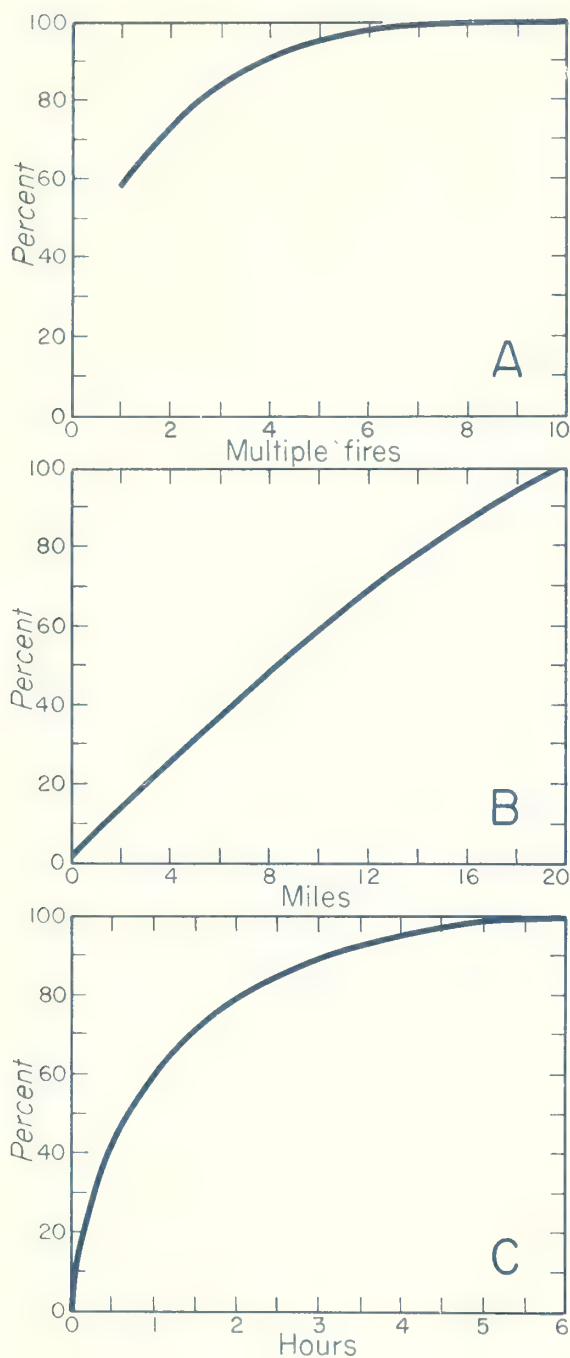


Figure 3—Cumulative distribution of 346 multiple fire starts on the Deschutes National Forest, Oregon, 1960-69: **A**—by number of later fire starts; **B**—by radial distance from initial fires; and **C**—by time span from initial fire starts.

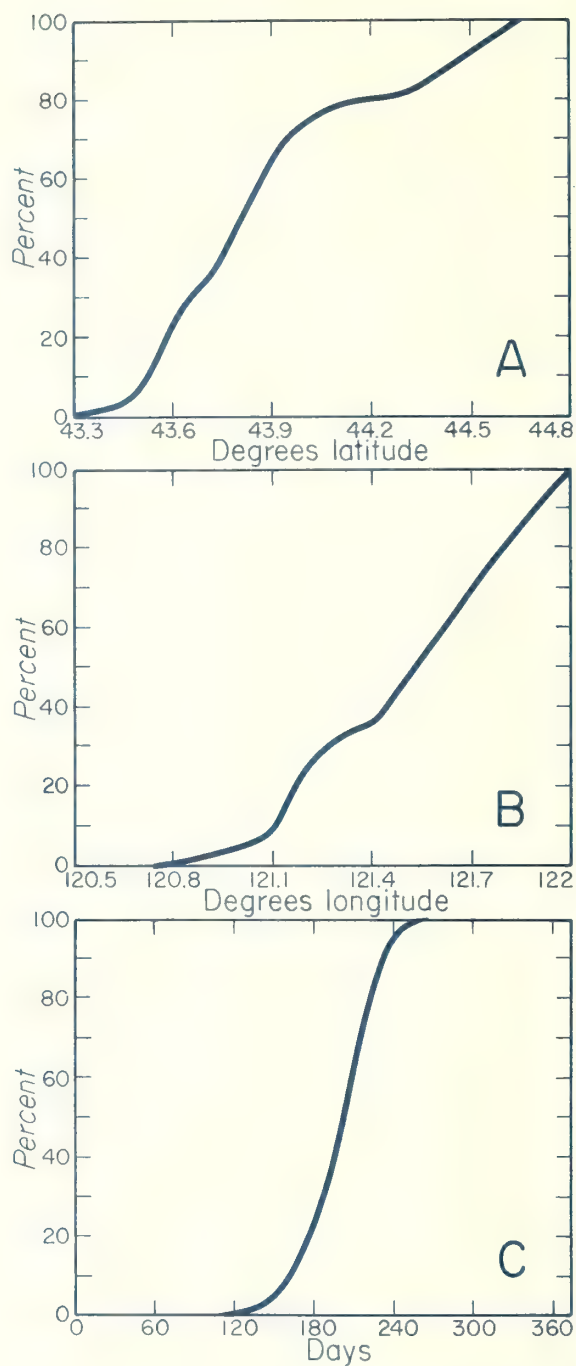


Figure 4—Cumulative distribution of 175 initial lightning fires, Deschutes National Forest, Oregon, 1960-1969; **A**—by latitude north; **B**—by longitude west; and **C**—by time of year.

in determining what detection capability should be and how to allocate forces for the initial control attack.

FIRE DETECTION AND INITIAL ATTACK TIME PROGRAM

The computer program developed to analyze detection or initial attack time allows examination of these two quantities or their sum as a function of the variables available from the 5100-29 data (size, weather, fuel, slope, etc.). Any other variable available from the form may be substituted for detection and initial attack time. To illustrate the output of this program, cumulative sample distributions are given here for combined detection and initial attack time as a function of three variables: size of fire (*table 2*),

Table 2—Cumulative distribution of combined detection and initial attack time, fires from all causes, on three National Forests in California, by size of fires, 1960-1969

Time (min.)	Angeles		Cleveland		San Bernardino	
	< 10	> 10	< 10	> 10	< 10	> 10
1	0.03	—	0.02	—	0.04	—
3	.04	0.03	.04	—	.02	—
5	.09	.06	.08	—	.04	—
8	.16	.16	.15	0.02	.10	0.05
10	.25	.22	.18	.07	.13	.07
12	.31	.38	.27	.14	.19	.14
15	.39	.52	.34	.21	.25	.28
21	.51	.63	.46	.29	.33	.49
30	.61	.79	.57	.53	.41	.68
39	.65	.85	.65	.63	.46	.73
60	.73	.92	.74	.77	.54	.83
90	.80	.96	.82	.86	.61	.89
180	.88	.97	.88	.87	.73	.92

Table 3—Cumulative distribution of combined detection and initial attack time, from all causes, on the San Bernardino National Forest, by type of fuel, 1960-1969

Time (min.)	Timber (748) ¹	Brush (365) ¹	Grass (296) ¹
3	0.01	0.02	0.04
6	.03	.05	.11
8	.05	.10	.21
10	.07	.12	.32
15	.12	.29	.51
18	.15	.35	.59
24	.19	.42	.69
30	.24	.50	.75
40	.29	.57	.85
60	.36	.65	.88
120	.51	.78	.93

¹Number of fires shown in parentheses.

Table 4—Cumulative distribution of combined detection and initial attack time for fires from all causes, on three National Forests in California, by burning index, 1960-1969¹

Time (min.)	Angeles		Cleveland		San Bernardino	
	B.I. below 28	B.I. above 28	B.I. below 28	B.I. above 28	B.I. below 28	B.I. above 28
3	0.04	0.06	0.03	0.03	0.01	0.02
5	.05	.07	.07	.06	.03	.06
6	.10	.13	.09	.07	.04	.08
9	.20	.20	.16	.11	.10	.15
12	.32	.29	.25	.30	.15	.25
15	.41	.40	.32	.38	.20	.35
18	.46	.47	.39	.43	.24	.43
24	.54	.62	.49	.55	.29	.51
30	.60	.75	.56	.60	.35	.59
45	.68	.84	.70	.66	.42	.69
60	.71	.88	.75	.67	.48	.73
90	.80	.92	.83	.81	.56	.78
180	.87	.94	.88	.84	.70	.84

Fires	Number					
	503	178	511	63	1,006	450

¹ B.I. = Burning index.

fuel (*table 3*), and burning index (*table 4*). (The following definitions are used: Detection time is the elapsed time from the estimated start time of the fire to the reported time of discovery; initial attack time is the elapsed time from detection to the time the first suppression action is started.)

SAMPLE DISTRIBUTION, GOODNESS-OF-FIT PROGRAM

The sample distributions given earlier are computed from the data-retrieval programs by a third program, which then attempts to fit the data with a known continuous distribution.

In the sample output from the second program (*table 5*), the data represent detection times (hours) for 204 class A fires (up to 0.25 acre). All were started by lightning. They cover all such fires during the years 1967-69 on the Clearwater National Forest.

The program attempts to fit the sample data with a set of known probability density functions by applying the Kolmogorov-Smirnov goodness-of-fit test (Whitney 1959). Six possible densities are available in the program.¹ While fitting the data, the program reduces the sample data to a histogram and sample distribution function $S_n(x)$. The detection times (hours) for the 204 class A fires can be fitted with a

Weibull distribution (with parameters $\lambda = .291$ and $\beta = .517$).¹ As a result, we can say, for example, that the probability of detecting a class A fire caused by lightning in less than 5 hours is

$$\begin{aligned}
 &= (1 - e^{(-.291 * 5^{.517})}) - (1 - e^{(-.291 * 0^{.517})}) \\
 &= 1 - e^{-.291 * 5^{.517}} \\
 &= 0.4876
 \end{aligned}$$

This type of goodness-of-fit test has some definite advantages over the standard Chi-square process (Hoel 1971). It is an exact method, whereas the Chi-square

method is only valid for reasonably large samples. Furthermore, in the classification of data, all frequencies need not exceed five observations.

The program is designed so that the user can delete or add new distribution functions to estimate the distribution of the data. The new distribution must be continuous, however, and one or more subroutines must be provided to evaluate the distribution of the sample data.

¹Mees, Romain M. *A method of fitting distributions to forest data*. 1972. (Unpublished report on file at Pacific Southwest Forest and Range Experiment Station, Riverside, Calif.)

Table 5—Detection times (elapsed hours) for lightning caused fires, class A size, Clearwater National Forest, 1967-69

0.0000	0.3000	1.6667	7.8167	14.0000	46.0000
0.0000	0.4167	1.6667	7.9167	14.0000	47.6667
0.0000	0.4167	1.6667	8.0000	14.3333	48.5000
0.0000	0.4167	1.9167	8.0000	14.5833	49.7500
0.0000	0.4500	2.0000	8.4167	14.8333	54.3333
0.0000	0.5000	2.0000	8.5000	15.0000	60.1000
0.0000	0.5000	2.1500	8.8333	15.0833	60.6667
0.0000	0.5000	2.4167	9.3333	15.5000	62.7500
0.0000	0.5833	2.8333	9.5000	15.5000	68.0000
0.0000	0.5833	3.0000	9.6667	16.8333	69.0000
0.0000	0.5833	3.0833	9.8333	17.0000	71.0000
0.0000	0.5833	3.5833	10.0833	17.1667	73.0833
0.0167	0.5833	3.6667	10.2500	17.8333	78.8333
0.0667	0.5833	3.8333	10.8333	18.0000	84.3333
0.0833	0.6667	4.0000	11.0000	18.0000	84.4667
0.0833	0.6667	4.6667	11.0333	18.3333	84.6667
0.0833	0.6667	4.6667	11.5000	18.4167	91.8333
0.0833	0.6667	4.8333	11.5000	18.5000	92.6667
0.0833	0.7500	4.8333	12.3333	19.3500	100.6500
0.1167	0.8333	5.0000	12.3333	19.5000	100.6500
0.1167	0.8333	5.1667	12.4167	19.5000	100.6500
0.1667	0.9167	5.3000	12.4667	21.5000	100.6500
0.1667	0.9167	5.5000	12.4667	22.8333	100.6500
0.1667	0.9167	5.7500	12.4833	24.7500	100.6500
0.1667	1.0000	5.9167	12.5000	26.3333	100.6500
0.1667	1.0000	6.0000	12.6667	31.0000	100.6500
0.1667	1.0000	6.4000	12.7500	31.7833	100.6500
0.1667	1.0833	6.6833	12.7500	35.0833	100.6500
0.1833	1.2500	6.7667	12.9167	35.2000	100.6500
0.2000	1.3333	6.8333	13.1667	36.1667	100.6500
0.2500	1.4000	7.4000	13.2333	37.1667	100.6500
0.2500	1.4167	7.4167	13.2500	38.0500	100.6500
0.2500	1.4167	7.5000	13.3333	38.9333	100.6500
0.2500	1.5333	7.6500	13.5000	44.5000	100.6500

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SYSTEMS ANALYSIS IN LAND-USE PLANNING... a conceptual development

Ronald A. Oliveira

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Oliveira, Ronald A.

1973. **Systems analysis in land-use planning . . . a conceptual development.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 8 p., illus. (USDA Forest Serv. Gen. Tech. Rep. PSW-5)

A planning model in which social, economic, and environmental constraints are specified—especially in mathematical form—can be helpful in decisionmaking. The general structure of a land-use decision model approached through systems analysis is described. The proposed procedures emphasize the quantification of interrelationships between uses and the specification of preferences and goals. The complexity of land-use planning is illustrated by an account of how the model might be applied on a Forest Service Ranger District of a National Forest in Colorado.

Oxford: 624:908:907.2.

Retrieval Terms: land-use decisionmaking; resource allocation; planning models; multiple-use management; systems analysis; Dillon Ranger District; Arapaho National Forest.

As population pressures have increased and national goals changed in past decades, land-use decisions have become increasingly complex and difficult. The reasons are not far to seek. Choices must be made between conflicting uses of resources. Necessary data and analysis of resource relationships are often lacking. Local objectives and problems have regional and national ramifications. As the manager of the National Forests, the Forest Service is confronted with particularly difficult and widely influential decisions, together with the need to make the basis of such decisions clearly evident. As a result, the improvement of planning methods has become an important concern of both the agency and the public.

A planning model in which social, economic, and environmental constraints are specified, especially in mathematical form, can be a valuable guide to decisionmaking. Such a model allows evaluation of the effects of policy alternatives and changing conditions. It can cover either a broad area, such as a region or a National Forest, or can be limited to a particular district or planning unit.

This report describes the general structure of a land-use decision model approached through systems analysis. Actual relationships are not developed in detail. The type of model presented is most suitable for determining the desirable balance of alternative resource uses for a specific area, in the context of the broad goals of Forest Service management. To illustrate the complexity of land planning, some problems facing the Dillon Ranger District, Arapaho National Forest, in Summit County Colorado, are described. Examples of some elements of the planning model are drawn from this area.

LAND-USE PROBLEMS

The multiple-use concept requires that a land unit be managed so as to achieve the best possible balance of resource uses. Such balancing may mean that a land unit is used less than its potential number of uses—if full utilization might impair the use of either that unit or another for a purpose to which it is peculiarly suited. The Forest Service Manual (Title 1, November 1, 1971) defines multiple use as the "management of all the various renewable surface resources of the National Forests so that they are utilized in the combination that will best meet the needs of the

American people. . . with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output." Multiple use, then, is not necessarily equal use; it means equal consideration for each resource in determining the "best" possible combination of uses. This outcome requires knowledge of how one use affects another, of how to measure present use and predict future demands, and how to weight different uses when conflicts arise.

Evaluation or weighting of the various conflicting uses can be troublesome. Besides the difficulty of collecting and analyzing data for such resources as timber and water there is the problem of quantifying the intangible, or at least unmarketable, products of National Forest use, such as the esthetic quality of a landscape or a wilderness experience. The value of such uses is evident in the costs incurred to experience them. Moreover, in order to experience such uses people often forego the opportunity to engage in other activities that may have a market-determined price or value.

The relationship of National Forest land use to that of surrounding areas is another source of problems. Land managed privately or by local communities, county, State, and other Federal agencies affects and is affected by National Forest management. Such relationships should be considered to achieve the aims of comprehensive multiple-use management. Varying origins of demand for a particular use must also be considered. Local demands may, for example, conflict with national ones. Too superficial an inventory and analysis of the relationships of non-National Forest resources and social and economic conditions will limit the usefulness of unit or District plans.

Thus, National Forest land-use planning must account for a complex system of interrelated elements. It seems reasonable that an empirical decisionmaking procedure for such planning should emphasize the need to explain the workings of the system.

DILLON RANGER DISTRICT

The Dillon Ranger District offers an illustration of the complexity of land-use problems on the National Forests. The District surrounds Dillon Reservoir. Here, most problems of land use arise from high

demands for recreation in several competing forms. Dillon Reservoir is a drawing card for water-related recreation activities and is a water supply facility for Denver. In addition, several ski developments are in the area. These two attractions and the general scenic beauty of the area have made it popular for second home and mountain condominium developments as well as for the usual day and weekend recreation uses.

These high recreation demands and the expanding activity in building have created an atmosphere of urgency concerning land-use planning in the Dillon area. Some development is occurring on areas with unstable soils, high pollution potential, and high fire hazards. Inadequate sewage facilities may lead to water pollution problems. Many of the new developments may also face water supply problems in the future.

Consequently, the Dillon Ranger District must consider these conditions in its planning. The surge of construction resulting from the impetus of winter sports and reservoir developments is occurring on private land adjacent to the National Forest. Thus, the National Forest serves as a "backyard play area" to these developments, and pressure on the capabilities of the Forest lands continues to rise. The Forest Service needs to know and stipulate the recreation capacity of various land types on the Forest and the capital requirements associated with varying levels of capacity. In addition, its fire prevention capabilities are facing increasing pressure from the higher population densities in subdivisions on private lands as well as from intensified use of the National Forest land.

Campground use on the Dillon Ranger District has been high in past seasons and is expected to grow unless terminated or otherwise controlled. Increasing fire and water pollution hazards of high campground use, as well as financial limitations, have obliged the District to consider the various alternatives; that is, should more campgrounds be built and who should build them, or should all camping be prohibited and public areas limited to day use?

Land exchanges are needed to facilitate judicious and coordinated development of both public and private lands. Developers are seeking more suitable sites along the Blue and Snake Rivers. It is also desirable to leave these areas as open space, however, to reduce flood hazards and maintain esthetic quality. Whether these areas are to become part of private subdivisions, or be left as open space, or become partly open space and partly subdivisions must be determined. These land exchange issues are an essential element in coordination of Forest Service land-use plans with those of the local communities and Summit County.

The variety of land-use problems in the Dillon area has resulted in the expression in multiple-use plans of intention to take specific actions. These actions (e.g., "Convert recreation sites to day use only" or "Retain and obtain in public ownership or open space maximum frontage along the Blue River") may eventually prove to be the "best" ones. But they appear to be preconceived solutions based on conventional wisdom, rather than the outcome of study or analysis, supported by facts, in a form understandable to the public. Perhaps a better planning procedure would be to consider all relevant relationships between land uses, public demands, ecosystems, etc., in the light of the principles of multiple-use management. By so doing it would be possible to set forth the policy actions needed to meet the goals of the Region, Forest, Ranger District, County, and State. The systems analysis approach seems the appropriate one.

SYSTEMS ANALYSIS APPROACH

A systems orientation implies a view of a system of elements as a whole, rather than individually. That is, this perspective emphasizes the interdependencies between the elements of the system and concentrates attention on their relationships (DeLucia *et al.* 1971; Churchman 1968).

Often the systems approach to complex problem solving requires data gathering and analysis by interdisciplinary teams. It is not always obvious in advance which disciplines will make the major contribution to the study. Viewpoints and procedures may be drawn from a variety of disciplines.

In the construction of large systems models, the gap between specialists is often bridged by a mathematical formulation. This formulation provides valuable guidance for research and data collection and allows the engineer, the economist, the biologist, and others to see how small but vitally important pieces of information and theory can merge, and to recognize critical gaps in existing information and knowledge. Mathematical models are tools of the systems approach. Their development and utilization provide a useful framework for integrating the contributions from various disciplines and for incorporating data and the research results from different fields.

Specifying System Boundary

The nature and scope of the particular problem at hand defines the system boundary—the "line" that surrounds those elements considered to be part of the system. In the "art of systems analysis," specifying

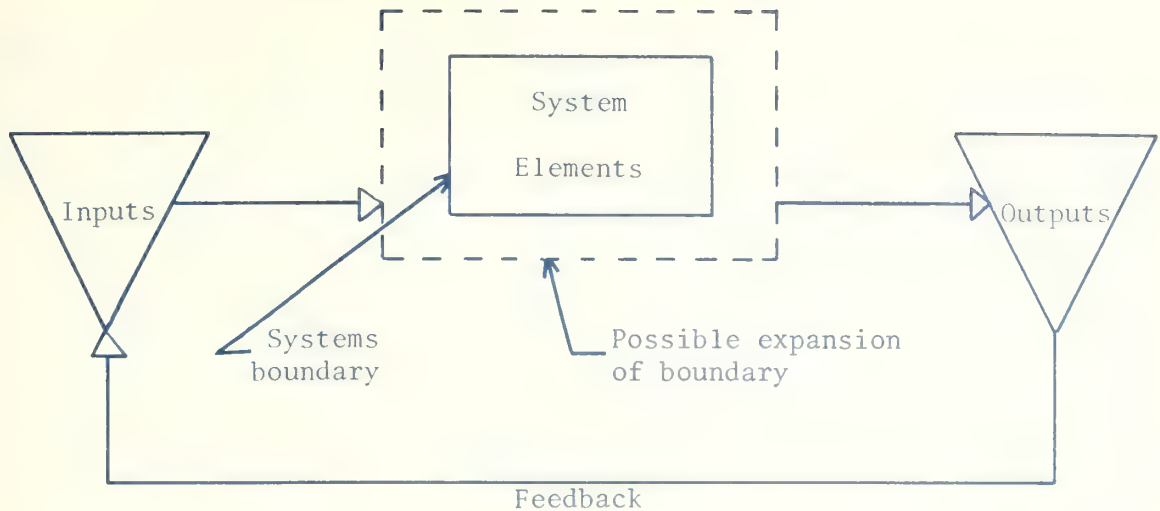


Figure 1—A basic system model consists of inputs, elements of the system, and the outputs. The boundary of the system can be expanded to cover problems whose scope widens during the systems analysis.

this boundary enables the user to choose the appropriate model to define the system. Land-use planning models are subjective in that the system boundary is not an objective datum perceivable through direct observation, but is largely a choice of the analyst, who arbitrarily classifies some borderline interactions as exogenous (outside the system).

The system boundary is specified to include those elements that are interrelated and pertinent to the set of decisions to be made. The boundary usually encloses those parts of the system that are subject to some degree of control. For example, if in planning for campground units it is assumed that the demand functions for campgrounds are known but that pricing policy is beyond the planner's control, then demands are noncontrolled. If, however, the planner can charge camping fees or establish quotas, demands are now at least partially controllable, and are considered endogenous to the system. In effect, the scope of the problem can expand or contract the system boundary definition. In addition, it can influence the degree of aggregation and approximation with which pertinent interacting elements are considered.

A system in simple terms is charted in *figure 1*. The system receives inputs—some controlled, others not—that affect the interaction of system elements. Outputs are produced which in dynamic systems may affect the inputs (feedback). The control decisions seek to achieve some objective or set of objectives. A simplified example of such a system could be a

National Forest campground area. The inputs would be demand for the campground, fees, and other campground regulations, type of sites, soil types and slopes, vegetation, etc. The system would be the interaction of these inputs, and the outputs would be environmental quality of the area, fire hazard, actual campground use, etc. These outputs in turn would have feedback effects on future inputs. Forest Service decisionmakers, recognizing the interactions within the system, would manipulate the controllable inputs, such as length-of-stay or limit, to achieve the outputs desired.

Evaluating Resource Uses

A systems analysis approach to the integrated control and use of National Forest resources provides for the examination and evaluation of a large number of possible resource uses. It does not necessarily, however, require the inclusion of all uses in the resource development plan. Inclusion or exclusion depends on the degree to which a particular use contributes to the broad objectives of land use, and on the extent to which the use is complementary to other desired uses. The danger exists that the attempt to be comprehensive may be used to guarantee the inclusion of certain preselected uses. A systems planning effort that is well designed and executed avoids this hazard.

In contrast to the traditional analysis of a particular function, a well-defined systems model allows decisionmakers to assess the degree of complementarity between purposes. Complementarity may be

considered a measure of the efficiency with which a land resource system can serve several purposes—sites for outdoor recreation, timber production, and wildlife habitat, for example. Complementarity exists when a stand of timber that is thinned to control disease and insect damage yields usable wood. Similarly, the thinning may improve stand growth and wildlife habitat. Different purposes are usually not perfectly compatible; for instance, timber harvesting and recreation seasons may coincide, and the removal of trees may temporarily reduce the esthetic quality of the landscape. If a system is developed and operated to obtain maximum efficiency for one resource use, then in general, less than full efficiency is achieved in other uses.

DEVELOPMENT OF A SYSTEMS MODEL

In general, the most appropriate situation for the application of systems analysis is one in which conditions are changing too rapidly for experience to be assimilated by informal, unsystematic methods, but slowly enough to permit the formulation of a model applicable to both the recent past and relevant future, and to permit the accumulation of the data needed (DeLucia, *et al.* 1971). Such a situation apparently exists in land-use planning, especially on the National Forests. The applicability of systems analysis to National Forest land-use planning has been broadly outlined earlier in this report. How a model can be developed is illustrated by using the Dillon Ranger District as an example.

The first step in analysis is to specify objectives (fig. 2). They constitute the framework in which choices between resource uses and alternative plans will be made. The general goals of management in the Dillon Ranger District are those of the Forest Service as a whole. The Forest Service has outlined its objectives and guides to policy in its *Framework for the Future* (USDA Forest Service 1970). One objective, for example, is to "protect and improve the quality of air, water, soil, and natural beauty." Another is to "promote and achieve a pattern of natural resource uses that will best meet the needs of people now and in the future." All 11 objectives listed presumably have equal priority, but in the decisionmaking process, some choice must be made to resolve potential or actual conflicts.

The aim should be to find a satisfactory compromise (possibly eliminating some uses), based on

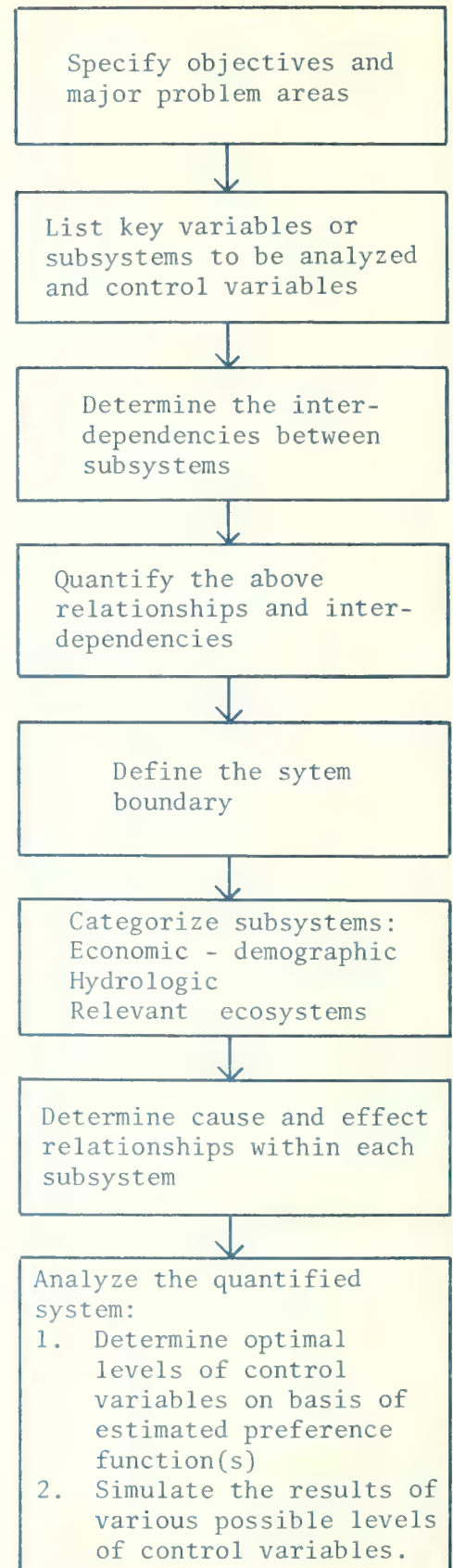


Figure 2—The systems analysis process may be viewed in terms of a flow chart.

analysis of the relative “costs” and “benefits,” both economic and environmental, of each use. Often, however, a measurement for uses other than the primary one, especially the “use” represented by maintenance of environmental quality, is difficult. In such instances, the cost-effectiveness approach may be employed to compare the net dollar benefits of the use foregone to preserve, for example, a certain number of undeveloped acres. If appropriate information is available, the number of undeveloped acres might possibly be related to numbers of certain specific species saved or protected. It should be noted, however, that this particular example is a problem of non-marketability in the benefit estimate, not intangibility.

The next step in the analysis is for each member of the interdisciplinary team to list those variables in his areas that should be explained by the system and to specify the structural form of the subsystems with which he will be concerned. For example, an economist might specify employment, production, and income as some of the relevant variables of an economic-demographic subsystem (*fig. 3*). The presumed causal relationships within each subsystem need to be formulated; in other words, each endogenous variable (e.g., employment in lumber manufacturing) will be expressed in a mathematical relationship as a function of various explanatory variables. The nature of these relationships must be specified, on a basis of available theory and empirical findings, either mathematically or verbally.

In addition to those functions making up the various subsystems, an account of other relationships central to specific problems or issues may be desirable in the over-all system. Some of these relationships may have already been specified in the subsystems. Examples of such relationships, in the form of questions applying to the Dillon area, are the following:

1. What is the effect of more recreation activity on water quality in the area?
 - a. How does this vary with the type of activity and the type of soil on which the activity takes place?
 - b. What is the limit of recreation capacity for Dillon Reservoir to preserve its water quality?
2. What is the effect of various forest land activi-

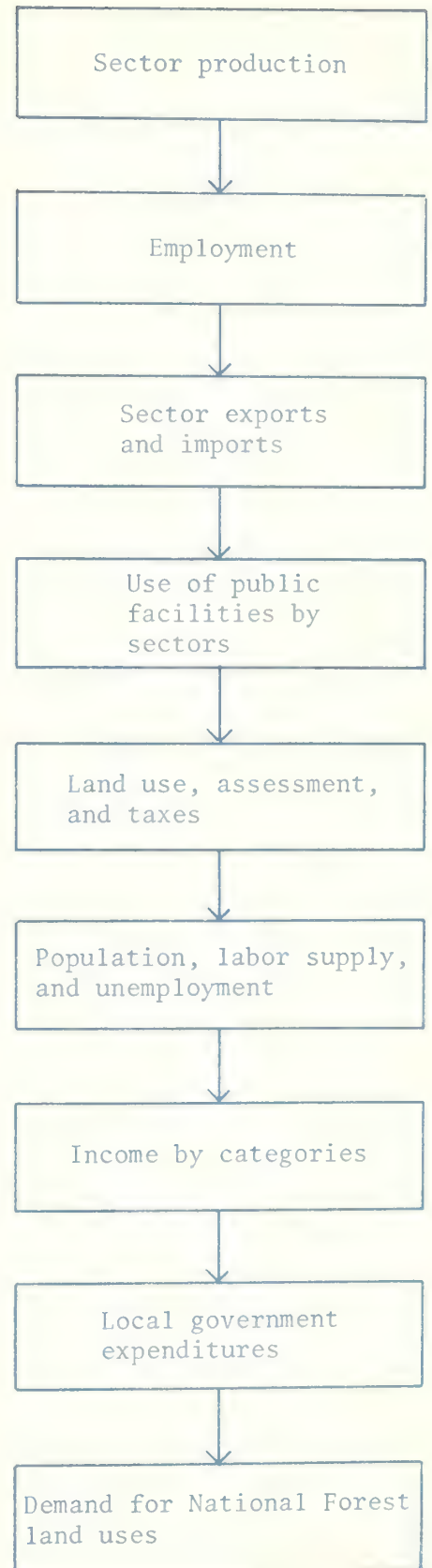


Figure 3—A simplified example of a hypothetical economic-demographic subsystem of this type may be formulated from theory and altered to fit the specific application. The arrows represent a possible causal relationship that would need to be verified empirically.

ties (timber harvesting, recreation, wildlife management, fire, etc.) on the environmental factors in the area (soil erosion, water quality, noise level, wildlife, scenic quality, etc.)?

3. How are different land uses interrelated or what are the trade-offs between uses?

4. What land areas are best suited for construction and which areas are not suitable?

5. What is the expected demand for ski areas in the Dillon area? Does this demand need to be met? If so, what are the suitable sites?

6. What will be the influence of the new I-70 tunnel on the area?

7. How will increasing urbanization or semi-urbanization affect the environmental quality of National Forest land?

Whenever feasible, demand relationships should be introduced into the land-use system. Traditionally, land-use plans have usually treated demand, which is different from use or participation, as an exogenous factor beyond the control of the local planning unit. Demand is influenced by local conditions, however, such as land taxes, zoning, fees, and building regulations. An understanding of the causal nature behind certain demands will enable the Forest Service to anticipate changes in demand and decide whether changes in supply are necessary.

Once the team has specified the structural form of the system, the mathematical or reduced form of each relationship must be specified. Statistical procedures for estimating the parameters of each relationship need to be selected. These procedures will often be limited by the availability of data. In fact, many of the functions or relationships may have to be approximated because data are limited. Often *a priori* parameter estimates may be obtained from previous studies or other analysts.

Once the above relationships have been quantified (that is, their parameters have been satisfactorily estimated), the land-use systems model is ready for analysis. For such a model two types of analytical technique are feasible: an optimization system and a simulation system.

Optimization Procedure

An optimization procedure would prove useful for decisionmakers in a policymaking framework. Often policy makers dislike the use of words (or procedures) such as "optimize" or "maximize." Such terminology is used in government planning guides, however, and specifically in the multiple-use directives of the Forest Service Manual (Title 2100,

November 1971): "Public goals established by people through political processes for the management of National Forest System and related lands require that their protection, development and use provide optimum public benefits."

As noted above, Forest Service decisions regarding land use must serve broad economic, social, and environmental objectives. When these goals are competitive, a higher level of attainment of one goal can be reached only by reducing the level of attainment of another goal. Thus, an implicit preference or objective function exists by which land planning decisionmakers weight the relative importance of the various goals when making choices. That is, they consider and weigh the trade-offs between actions. Obviously, such evaluation should be evident, if possible, in the planning system.

Procedures for estimating the parameters or weights of a preference function for policy analysis have been discussed by others¹ and are beyond the scope of this report. One approach is worth mentioning, however. The system team or analyst chooses several land-use planning objectives. (This procedure is similar to that proposed by Van Eijk and Sandee (1959).) They then attempt to obtain the ratios or trade-offs between the various variables entering the preference function. These ratios or "barter terms" indicate the willingness of policymakers to sacrifice one variable for a certain amount of another variable without changing the value of the preference function. That is, the analyst attempts to ascertain points of indifference. "The coefficient of each target is then obtained as the (geometric) average of the barter terms of that target against all other targets (and against itself, which terms are obviously unity)" (Van Eijk and Sandee 1959, p. 4). Thus, the preference function might be formulated for a group of individuals who shape government policy on a committee and consulting type basis. In reality, such a situation is highly probable since policy actions may be decided by government officials, but influenced by many others such as advisors, pressure groups, labor leaders, and various technical experts. To estimate the

¹For examples, see the paper *A conceptual regional economic model incorporating policy considerations*, by R. A. Oliveira and G. C. Rauser, presented at the Western Economic Association annual meeting, Davis, Calif., Aug. 27-28, 1970; and the paper *Estimation of social preference functions for the analysis of economic policy problems*, by G. C. Rauser and J. W. Freebairn, presented at the American Agricultural Economics Association annual meeting, Gainesville, Florida, Aug. 20-23, 1972 (copy on file at Dep. Agric. Economics, Univ. Calif., Davis, Calif.).

subjective barter terms underlying the preference function of such a group, Van Eijk and Sandee (1959, p. 4) propose a method which they refer to as imaginary interviewing. In other words, they feel that an actual interviewing of policy makers to ascertain their preferences would not be possible. They suggest a type of imaginary interviewing or actually a reviewing of written and spoken policy statements.

The objectives of Forest Service management are clearly stated and communications between staff and line decisionmakers are fairly open. Therefore either the imaginary or straightforward interviewing procedure may prove feasible. In addition, this method could easily be used to construct several possible preference functions rather than a single one. These could reflect the extreme viewpoints and preferences of different central decisionmakers (or different citizens' groups) involved in the planning process, as well as viewpoints lying between these extremes. Thus, the analysis team could present the policy decisionmaking group with a series of assessments based on a variety of objective functions, leaving the policy group to make its own choice as to which one best reflects (or is closest to) their preferences or objectives.

Where objectives are not complementary, but where they can be ranked in order of preference or priority, the analyst could specify a ranking or ordering of objectives where the last objective consists of a few variables that could be combined in a preference function. That is, satisfactory levels (e.g., satisfactory water quality standard) would be specified for all variables except those in the last objective, and preference weights would need to be determined for these few variables only. The weighted combination of these variables would then be maximized subject to satisfactory levels of all prior objectives or goals.

Simulation Procedures

If it is not possible to specify an objective function, then the land-use systems model may be analyzed by simulation procedures. In other words, the analyst could vary the magnitude of certain variables and/or parameters and simulate the effects on the system. Experiments could be performed on the model to see how sensitive the outputs were to various assumptions, variables, parameters, or forecasts. In addition, certain policy actions could be tested and their results observed. If several such tests were made, policymakers could observe the results of their actions and thus make better decisions.

A hypothetical simple simulation model for camp-

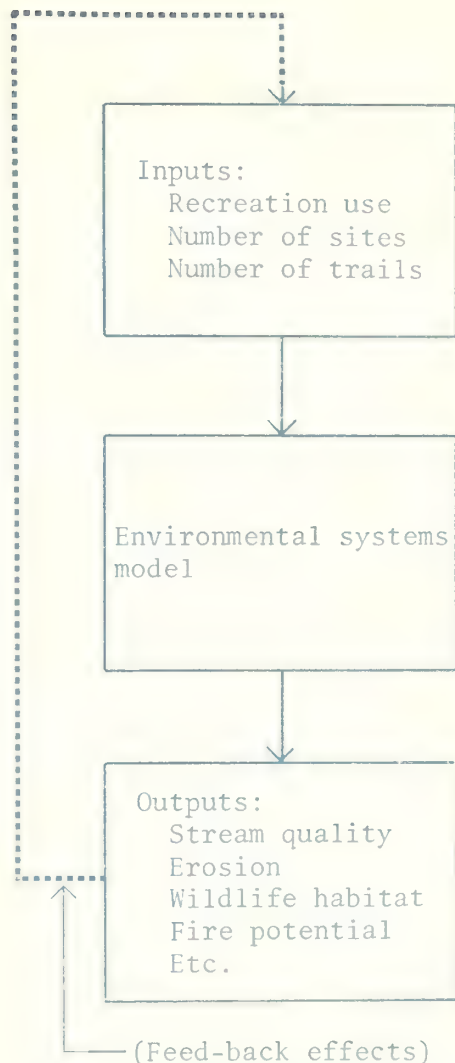


Figure 4—Hypothetical simulation model of campground use.

ground management is given in *figure 4*. The inputs would be recreation use in camper days and land management decisions, such as the number of camping sites and trails. The model would show how these inputs interact with the local environment (or ecosystem). Plausible outputs could be various environmental measures. The effects of various inputs (such as different use rates) could be simulated with the model. A more sophisticated approach would treat recreation use as an endogenous output which would be a result of the interactions within the system.

CONCLUSION

The land-use systems model and the analysis methods I have described are in accord with the Forest Service's multiple-use planning unit concept.

Planning units could easily serve as boundaries for land use systems. The Forest Service Manual (Title 2100, Directive 1, Section 2126, Nov. 1971) describes such units as "specific, identified and delineated land areas. Smaller than Planning Areas, they are large enough to encompass most of the meaningful or significant relationships within a drainage or series of drainages. The purpose of Planning Units is to provide a focus for planning activities in a small enough area to be workable and large enough to enable the planning team to envision or predict the cause and effect relationships of management alternatives...."

The proposed land-use planning systems analysis could easily meet the analysis requirements as specified in the Forest Service Manual. The use of an objective function would indicate how alternative plans contribute to goals and would indicate the trade-offs between alternatives. In addition, the construction phase of the model would point out any data or inventory limitations which may exist.

The systems analysis approach seems well suited to Forest Service land use planning. It allows for analysis, experience, judgments, and revisions to enter the decisionmaking process. Proposed programs can be examined in relation to various objectives, both economic and social, of local and regional programs. This type of multidiscipline approach is needed to solve problems having a wide range of alternative solutions. The effects of such alternatives can be displayed in multiobjective accounts framework that can then be used in policy discussion and in other studies and programs. In addition, the systems planning

approach has cumulative value in that information and operation costs incurred in one area may be applicable to National Forest planning problems in other areas.

Obviously implementing the systems approach to National Forest land use planning would not be easy; investments would be required in system analysis, computer time, and supporting facilities. The investments in time and money would be small, however, minuscule compared with the total costs of managing the National Forests. Complex and sophisticated procedures are now in use in such areas as timber management, watershed management, and forest engineering. The land use decision process could profitably be analyzed with the same rigor.

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VERTEBRATE FAUNA OF THE SAN JOAQUIN EXPERIMENTAL RANGE, CALIFORNIA: a checklist

Thomas F. Newman Don A. Duncan

PACIFIC
SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
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USDA FOREST SERVICE
GENERAL TECHNICAL
REPORT PSW-6 /1973

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Newman, Thomas F., and Don A. Duncan

1973. **Vertebrate fauna of the San Joaquin Experimental Range, California: a checklist.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 17 p. (USDA Forest Serv. Gen. Tech. Rep. PSW-6)

This report updates an earlier checklist, published in 1955, of vertebrate fauna found on the San Joaquin Experimental Range, in Madera County, California. Nineteen new species have been recorded since 1955. This report records the occurrences of seven fish, eight amphibians, 19 reptiles, 38 mammals, and 149 birds. References to research on individual species are included.

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Retrieval Terms: vertebrata; checklists; San Joaquin Experimental Range; California.

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Since research began at the San Joaquin Experimental Range, Madera County, California, in the 1930's, the relationships between wildlife, vegetation, and cattle have been integral parts of the research program. In cooperation with individuals and other organizations, the Pacific Southwest Forest and Range Experiment Station has participated in and encouraged studies of many basic biological subjects. Agencies and institutions that have taken part include the U.S. Fish and Wildlife Service, California Department of Fish and Game, University of California, and California State University, Fresno. A list of the publications about research at the Experimental Range (Sanderson and Duncan 1966) is currently being revised.

The San Joaquin Experimental Range lies in the lower Sierra Nevada foothills of central California. Elevations range from 700 to 1,700 feet on the 4,500 acres. Soils (Awahnee and Visalia series) are of granitic origin, and have low capacity for storing water. Winters are mild and moist; summers are hot and dry. Rainfall averages about 19 inches, with extremes of about 10 and 32 inches. The Experimental Range is in the annual plant-oak woodland type, and includes grassland, savanna, and occasionally dense stands of trees and brush.

The zoologically oriented studies on the Experimental Range have dealt chiefly with life histories of major rodent species, their impact on range forage, food habits and management of quail, and food habits of predators. Most recorded occurrences of birds are the result of occasional observations by scientists and technicians—not from formal studies.

This report updates an earlier checklist of vertebrate fauna of the Experimental Range (Childs and Howard 1955), and provides additional information. It lists all species recorded since 1955. That earlier list is now out of print. Specimens of most species are in a collection at the Experimental Range. Only species seen within the Range boundary are included in this updated list.

Scientific names used are in accordance with these sources: fish—Kimsey and Fisk (1960); amphibians and reptiles—Stebbins (1966); mammals—Ingles (1965); birds—American Ornithologists Union (1957) and Grinnell and Miller (1944).

FISH (7)

The occurrence of fish at the Experimental Range depends on introduction into artificial ponds. Two dry years (1971-72) in a row caused the one reservoir with a fish population to become dry. In January 1973, no fish populations occurred on the Range except mosquito fish in a few large concrete water troughs. In early 1973, large-mouth bass, bluegill, Sacramento perch, and mosquito fish were stocked in an experiment designed to provide baseline fish production data from foothill ranch ponds.

Checklist of Fish

Mosquito fish	(<i>Gambusia affinis</i>)
Large-mouth bass	(<i>Micropterus salmoides</i>)
Hitch	(<i>Lavinia exilicauda</i>)
Green Sunfish	(<i>Lepomis cyanellus</i>)
Bluegill	(<i>Lepomis macrochirus</i>)
Red-ear Sunfish	(<i>Lepomis microlophus</i>) ¹
Sacramento perch	(<i>Archoplites interruptus</i>) ¹

AMPHIBIANS (8)

The semi-arid conditions in the foothill belt of California are not suitable for a large or varied amphibian population. One introduced species, the bullfrog, is found in reservoirs. Two Anurans, the Pacific tree frog and the Western spadefoot toad, are the most abundant members of this group (Cohen and Wood 1953).

¹New species recorded since 1955.

Checklist of Amphibians

California newt	Western toad
Tiger salamander	Pacific tree frog
Slender salamander	Red-legged frog
Western spadefoot toad	Bullfrog

California newt (*Taricha torosus sierrae*). Rare.

Kenneth A. Wagnon recalls observing the California newt occasionally in the 1930's. Although no newts were seen in 1950-51, two specimens were taken in spring 1952. Several were seen in spring 1963 by Don A. Duncan.

Tiger salamander

(*Ambystoma tigrinum californiense*). Rare.

Found in limited numbers near the dams in the headquarters area. On February 22, 1952, eggs were found where the horse pasture dam used to be. Several albino larvae were taken in 1950-51. One found by William H. Kruse in headquarters area July 10, 1963. One or two seen most years by Don A. Duncan since 1963.

Slender salamander

(*Batrachoseps a. attenuatus*). Uncommon.

Found under rocks and logs in the wet season.

Western spadefoot toad

(*Scaphiophus h. hammondi*). Abundant.

The spadefoot breeds in vernal pools and intermittent streams in varying numbers depending on weather conditions in early spring. Singing begins in late January with most egg production in March. Albino larvae are occasionally found. Reference: Childs (1953).

Western toad

(*Bufo boreas halophilus*). Common.

These toads may be found foraging at night. Eggs were found on February 22, 1952, where the horse pasture dam used to be.

Pacific tree frog (*Hyla regilla*). Rare.

Found in wet areas throughout the year where it breeds in streams and vernal pools.

Red-legged frog (*Rana aurora draytoni*). Rare.

One was observed in October 1951. The yellow-legged frog (*Rana boylei*) has not been observed at the Range, although both of these species are present at O'Neals, 3 miles away.

Bullfrog (*Rana catesbeiana*). Common.

Formerly abundant before the destruction of the

horse pasture dam in 1951. References: Cohen and Howard (1958), Howard (1950).

REPTILES (19)

Reptiles appear well suited to the climate of the Experimental Range as indicated by their numbers and diversity of kinds. Three lizards—Gilbert skink, whiptail lizard, Western fence lizard—and two snakes—Pacific gopher snake and Pacific rattlesnake—are the most abundant species.

Checklist of Reptiles

Lizards (6)

Western fence lizard
Side-blotched lizard
Pacific Coast
horned lizard
Gilbert skink
Whiptail lizard
Southern alligator
lizard

Turtles (1)

Pacific mud turtle

Snakes (12)

Western ring-necked snake
Western yellow-bellied racer
California striped whipsnake
Pacific gopher snake
King snake
Mountain king snake¹
Long-nosed snake
Sierra Nevada garter snake
Giant garter snake¹
Red-sided garter snake
California spotted night snake
Pacific rattlesnake

Lizards (6)

Western fence lizard

(*Sceloporus o. occidentalis*). Abundant.

The first lizard to become active in the spring, generally on warm days in February or March. Found around buildings, rock outcrops, and trees.

Side-blotched lizard

(*Uta stansburiana hesperis*). Common.

Found in sandy areas where escape burrows are present.

Pacific Coast horned lizard

(*Phrynosoma coronatum frontale*). Rare.

Observed in the later 1930's, but only one has been recorded in recent years (1966).

Gilbert skink

(*Eumeces g. gilberti*). Abundant.

This species and the whiptail lizard are taken abun-

¹ New species recorded since 1955.

dantly in drift traps. The skink appears to be active only from April to June in dense vegetation.

Whiptail lizard

(*Cnemidophorus tigris mundus*). Abundant.

Found in sparse vegetation and along roads; active during the entire summer.

Southern alligator lizard

(*Gerrhonotus multicarinatus webbiai*). Rare.

Only a few have been recorded in the headquarters area. One collected May 28, 1961 by Jack N. Reppert on patio of guest rooms. One found at northern edge of Experimental Range by Don A. Duncan, May 2 1973.

Turtles (1)

Pacific mud turtle

(*Clemmys marmorata*). Uncommon.

Presence of the reservoir allows a few introduced individuals to reproduce themselves.

Snakes (12)

Western ring-necked snake

(*Diadophis amabilis pulchellus*). Rare.

A few have been recorded along the swale in headquarters area. One collected February 20, 1961 under rocks in Range Unit 5-1 by Don A. Duncan. One seen in Range Unit 9 in 1962 by Stanley L. Anderson.

Western yellow-bellied racer

(*Coluber constrictor mormon*). Uncommon.

Taken occasionally in the drift traps in headquarters area.

California striped whipsnake

(*Coluber lateralis*). Common.

Widespread on the Range.

Pacific gopher snake

(*Pituophis c. catenifer*). Abundant.

Widely distributed over the Experimental Range, perhaps more abundant than the rattlesnake (Howard 1949).

King snake

(*Lampropeltis getulus californiae*). Common.

Found in small numbers on the Experimental Range. One found ingesting a rattlesnake and photographed by Stanley E. Westfall in 1972.

Mountain king snake

(*Lampropeltis zonata*).¹ Rare.

One found dead on road in 1965 by Don A. Duncan; live specimen found in Range Unit 5-3 in April 1967 by Duncan.

Long-nosed snake

(*Rhinocheilus l. lecontei*). Rare.

Drift trap records indicate a greater abundance of this snake than was once believed.

Sierra Nevada garter snake

(*Thamnophis elegans couchii*). Common.

Found along streams (Fitch 1941).

Giant garter snake

(*Thamnophis elegans gigas*).¹ Rare.

First seen March 1972, in pond in Range Unit 9. Specimen captured, identified, and released May 21, 1972 by Don A. Duncan. Thomas F. Newman observed one attempting to swallow a 5-inch bluegill at the reservoir in Range Unit 9 on July 2, 1972. Listed as a "Rare" species in California (Leach and Fisk 1972).

Red-sided garter snake

(*Thamnophis sirtalis tetrataenia*). Common.

Limited to moist areas.

California spotted night snake

(*Hypsiglena torquata nuchalata*). Rare.

Recorded in rock outcrops in walls of wells.

Pacific rattlesnake

(*Crotalus viridis oreganus*). Abundant.

A thorough study of the habits of this species has been made. A population of one per acre is estimated (Fitch 1949; Fitch and Glading 1947; Fitch and Twining 1946; Fitch and Wagon 1947).

MAMMALS (38)

Most of the mammalian investigations have concerned rodents because these animals occur in great numbers and also because their undesirable effects on forage production become of economic significance.

Checklist of Mammals

Virginia opossum	Adorned shrew
Broad-footed mole	Yuma myotis

¹ New species recorded since 1955.

California myotis	Botta pocket gopher
Western pipistrelle	San Joaquin Pocket mouse
Red bat	California pocket mouse
Pallid bat	Heermann kangaroo rat
Mexican free-tailed bat	Muskrat ¹
Raccoon	Southern grasshopper mouse
Long-tailed weasel	Western harvest mouse
Spotted skunk	Deer mouse
Striped skunk	Brush mouse
Badger	Pinon mouse
Gray fox	Dusky-footed wood rat
Coyote	California meadow mouse
Mountain lion	House mouse
Bobcat	Yellow-haired porcupine
Beechey ground squirrel	Black-tailed hare
Merriam chipmunk	Audubon cottontail
Gray squirrel	Mule Deer

Virginia opossum

(*Didelphis v. virginiana*). Common.

One was recorded in an owl pellet (Fitch 1947b). First live animal reported by Donald L. Neal, December 1, 1957. Second live record by Jack N. Reppert, June 10, 1958. Several live animals were reported seen during the 1960's and the early 1970's.

Broad-footed mole

(*Scapanus l. latimanus*). Rare.

Two specimens were taken in gardens at headquarters in March 1953. Don A. Duncan reports moles are fairly common in the headquarters area; burrows are apparent, but animal not often seen.

Adorned shrew (*Sorex o. ornatus*). Rare.

One was caught in a drift trap on April 1, 1951. The specimen is located at the University of California Museum of Vertebrate Zoology, Berkeley.

Yuma myotis

(*Myotis yumanensis sociabilis*). Common.

Found at night in barns and around adobe buildings.

California myotis

(*Myotis c. californicus*). Common.

Habits are the same as the Yuma myotis.

Western pipistrelle

(*Pipistrellus hesperus merriami*). Common.

This early evening flyer was first collected in June 1950.

Red bat (*Lasiurus borealis teliotis*). Rare.

Recorded only in an owl pellet by Fitch (1947b).

Pallid bat

(*Antrozous pallidus pacificus*). Abundant.

Not recorded on the Range by J. T. Wright in 1937, but the pallid bat is now an abundant night roosting bat in the barns and adobe buildings. Jay C. Quast observed them flying out of holes in a blue oak at dusk during summer 1949. Studies on this species have been conducted by Sherman F. Wood and Henry E. Childs, Jr.

Mexican free-tailed bat

(*Tadarida mexicana*). Common.

Only a few records in early spring have been obtained while they were night roosting with the pallid bat.

Raccoon (*Procyon lotor psora*). Common.

Widespread over the Range along swales.

Long-tailed weasel

(*Mustella frenata xanthogenys*). Rare.

One was captured in the drift traps on May 6, 1950.

Spotted skunk

(*Spilogale gracilis phenax*). Rare.

Two, both road kills, found in 1951-52.

Striped skunk

(*Mephitis mephitis occidentalis*). Uncommon.

A few individuals have been trapped or seen.

Badger (*Taxidea taxus neglecta*). Common.

Although badgers are not often seen—even at night—their diggings indicate they are present.

Gray fox

(*Urocyon cinereoargenteus townsendi*). Rare.

Few foxes have been seen in recent years. Childs and Howard (1955) listed this species as common, but only three separate sightings were reported in 1971 and 1972. On January 28, 1973, Thomas F. Newman saw an individual near the stone bridge on the entrance road.

¹ New species recorded since 1955.

Coyote (*Canis latrans*). Common.

No control effort has been made since 1960. Coyotes have been commonly seen and heard in recent years. No cattle have ever been reported killed by coyotes. Calves dying from other causes have been scavenged by coyotes. Fitch (1948b) reported on the coyote at the Experimental Range.

Mountain lion

(*Felis concolor californica*). Rare.

Several sight records have been made since 1934. A few deer kills have been made on the Experimental Range by mountain lions.

Bobcat (*Lynx rufus californicus*). Common.

Frequently sighted now. No control effort has been made since 1960. Population is thought to be increasing. No cattle losses from bobcats have ever been reported.

Beechey ground squirrel

(*Spermophilus beecheyi fisheri*). Abundant:

This species is very important ecologically and economically to foothill rangelands. Many investigators have studied the life history of this animal, including Fitch 1947c, 1948c; Fitch and Bentley 1949; Horn and Fitch 1946; Howard 1951, 1959; Howard and Wagnon 1951; Howard, Wagnon, and Bentley 1959. The movements, population dynamics, and food habits of these squirrels and their relationship to cattle grazing are being studied in cooperation with the U.S. Fish and Wildlife Service. No control measures have been applied since 1962.

Merriam chipmunk

(*Eutamias m. merriami*). Uncommon.

This species seems restricted to rock outcrops where brush or fallen trees are found. J. T. Wright indicates that it may have been more abundant in former years. Seems to be rather common in suitable habitat. Frank Schitoskey (pers. commun.) reports that now (1973) chipmunks are more common than the San Joaquin pocket mouse.

Gray squirrel (*Sciurus g. griseus*). Uncommon.

The gray squirrel is found in association with digger pines. It is probably exposed to greater predation here than in most parts of its range because of the necessity of moving from tree to tree on the ground.

Botta pocket gopher

(*Thomomys bottae mewa*). Abundant.

Howard and Childs (1955) reported that: "This

species perhaps surpasses the ground squirrel for the title of the most destructive rodent on rangelands, because they occur in much greater numbers. It was found that 32 per acre reduced forage by 25 percent. . . . An aboveground dispersal has been demonstrated by the drift trap study." Others who have reported on the species are Howard (1952a, 1952b, 1953), Howard and Childs (1959), Morejohn and Howard (1956), and Ratliff and Westfall (1971). Movements and food habits are being studied in cooperation with the U.S. Fish and Wildlife Service.

San Joaquin pocket mouse

(*Peroganthus i. inornatus*). Common.

Appears to be common where vegetation is sparse.

California pocket mouse

(*Peroganthus californicus ochrus*). Uncommon.

Only irregularly taken.

Heermann kangaroo rat

(*Dipodomys heermanni tularensis*). Common.

At one time very abundant. A change from "perhaps 30 per acre to only one," during the period 1935 through 1946 was reported (Fitch 1948). Frank Schitoskey reported this species is even less abundant than one per acre from study results in 1972-73.

Muskrat (*Ondatra zibethica*).¹ Rare.

Three were seen on the reservoir in Range Unit 9 during 1971. Two were killed September 10, 1971; a dead muskrat was seen at the reservoir on July 2, 1972. One live one seen July 8, 1972.

Southern grasshopper mouse

(*Onychomys torridus tularensis*). Rare.

Reported only in association with *Lotus scoparius* in the big canyon below headquarters. An attempt to find them in this area in the summer of 1952 was unsuccessful.

Western harvest mouse

(*Reithrodontomys megalotis longicaudus*).

Uncommon.

Found in the swale areas in ungrazed pastures.

Deer mouse

(*Peromyscus maniculatus gambeli*). Abundant.

The deer mouse is found in open grazed pastures away from rocks or brush.

¹New species recorded since 1955.

Brush mouse (*Peromyscus b. boylei*). Abundant.
Found generally in rock outcrops (Howard 1957).

Pinon mouse
(*Peromyscus truei gilberti*). Abundant.

This species is most abundant in ungrazed brush. The relative abundance of the three species of *Peromyscus* may be interpreted from the following summary of total catch in standardized trap lines in two grazed pastures and in the ungrazed natural area during October 1951, April and October 1952, and April 1953. The numbers caught were: *P. boylei*, 43; *P. Truei*, 20; *P. maniculatus*, 11; *Perognathus inornatus*, 6; *Dipodomys*, 5; *Neotoma*, 2; *Riethrodontomys*, 1; *Eutamias*, 1; Total 89.

Dusky-footed wood rat
(*Neotoma fuscipes streator*). Common.

The wood rat is widely found in brush and rock outcrops.

California meadow mouse
(*Microtus californicus mariposae*). Uncommon.

The meadow mouse is restricted to ungrazed areas where it may become abundant. A cyclic peak in abundance was observed in 1951. In 1972 and 1973 Frank Schitoskey reported no captures of this species with intense trapping effort in suitable habitat.

House mouse (*Mus musculus*). Rare.

Only an occasional individual was taken in the headquarters area.

Yellow-haired porcupine
(*Erethizon dorsatum*). Rare.

One was reported some years ago by Kenneth A. Wagon and one was found dead on the entrance road in June, 1953. No live specimens reported from 1960 through 1972.

Black-tailed hare
(*Lepus c. californicus*). Uncommon.

Occasional individuals or family groups are seen.

Audubon cottontail
(*Sylvilagus audubonii vallicola*). Abundant.

It is widely distributed over the Experimental Range, often seen in numbers in the evenings during summer on lawns around headquarters (Fitch 1947a; Herman and Jankiewicz 1942).

Mule deer (*Odocoileus hemionus*). Common.
Apparently deer have greatly increased in numbers

since 1934. Horn and Fitch (1942) fail to mention deer as occurring on the Experimental Range. Childs and Howard (1955) estimated the resident population at about a dozen animals, with no apparent migrants. Deer continued to increase during the 1960's until the population is now probably in excess of 100 animals.

BIRDS (149)

Much has been written of the avifauna of California. Yet works restricted to the upper Sonoran zone, and to particular localities in it, are rare. The following accounts picture the bird populations in the foothill areas of the central part of the State as shown by the records made at the San Joaquin Experimental Range. The following definitions of status are used:

Permanent resident—a nesting bird found throughout the year.

Summer resident—a nesting bird found only during the nesting season.

Winter resident—a non-nesting species found only in winter.

Migrant—a non-nesting species found in the fall and/or spring, but rare or absent at other times.

Vagrant—a bird that has drifted from normal migration routes or its usual seasonal life zone; may also be a pioneer.

Casual—a species that is markedly irregular in occurrence from one year to another.

Residents are classed according to relative abundance: 1 (most abundant), 2, and 3 (least abundant).

For detailed accounts of the distribution of the birds recorded, see Grinnell and Miller (1944). Where species status has been determined from specimens, this has been added to the scientific name; the common name of the species has been used in every instance.

Checklist of Birds

The following three lists include only the nesting species and winter residents. The migrants, casuals, and vagrants appear in the annotated list. The status of some birds is tentative; further observations are needed to clarify their status.

Permanent Residents (38)

Wood duck ¹	Sparrow hawk
Cooper's hawk	California quail
Red-tailed hawk	Killdeer

¹ New species recorded since 1955.

Mourning dove	Brown creeper
Roadrunner	Wrentit
Barn owl	Bewick's wren
Screech owl	Canyon wren
Great horned owl	California thrasher
Anna's hummingbird	Western bluebird
Red-shafted flicker	Loggerhead shrike
Acorn woodpecker	Starling ¹
Downy woodpecker	House sparrow
Nuttall's woodpecker	Western meadowlark
Black phoebe	Brewer's blackbird
Scrub jay	House finch
Common raven	Lawrence's goldfinch
Plain titmouse	Brown towhee
Common bushtit	Lark sparrow
White-breasted nuthatch	Rufous-crowned sparrow

Summer Residents (14)

Turkey vulture	House wren
Western kingbird	Blue-gray gnatcatcher
Ash-throated flycatcher	Phainopepla
Western wood pewee	Red-winged blackbird
Violet green swallow	Bullock's oriole
Barn Swallow	Brown-headed cowbird
Cliff swallow	Black-headed grosbeak

Winter Residents (15)

Sharp-shinned hawk	Audubon's warbler
Lewis' woodpecker	Purple finch
Yellow-bellied sapsucker	Rufous-sided towhee
Say's phoebe	Oregon junco
Rock wren	Gambel white-crowned
Mockingbird	sparrow
Robin	Golden-crowned sparrow
Ruby-crowned kinglet	Lincoln's sparrow

Eared grebe

(*Podiceps caspicus*).¹ Casual winter visitant.

One seen on reservoir in Range Unit 9 on October 8, 1958 by Robert F. Buttery.

Pied-billed grebe

(*Podilymbus podiceps*). Casual winter visitant.

Between September 29, 1951 and March 21, 1952, individuals were observed on six occasions on the reservoir; however, none were seen the following year.

White pelican

(*Pelecanus erythrorhynchos*). Rare migrant.

A flock of 40 was observed in flight March 30, 1953.

Great blue heron

(*Ardea herodias*). Summer visitant.

Can be seen at reservoirs fairly often.

Green heron (*Butorides virescens*).¹ Casual.

Seen at reservoir on April 18, 1957 and May 18, 1958 by Robert F. Buttery.

Common egret

(*Casmerodius albus*). Casual summer visitant.

Formerly found at the horse pasture dam during the summer, but has not been recorded since September 1951.

Black-crowned night heron

(*Nycticorax nycticorax*). Casual.

One was heard calling in flight at night October 7, 1952.

Least bittern (*Ixobrychus exilis*). Casual.

One female was trapped alive in a drift trap along the swale at headquarters April 16, 1950, and released.

Canada goose (*Branta canadensis*).

Winter migrant.

Flocks have been seen in December and January in flight perhaps either to or from Lake Millerton, 6 miles away. Occasionally flocks have been seen feeding on new grass in open areas.

White-fronted goose

(*Anser albifrons*). Casual winter migrant.

A flight of 35 was recorded on December 7, 1951.

Snow goose

(*Chen hyperborea*).¹ Casual winter migrant.

A flock of 25 reported December 12, 1967 by Don A. Duncan.

Mallard

(*Anas platyrhynchos*).

Sporadic resident—winter migrant.

Mallards formerly bred in the region of the horse pasture dam. Pairs were seen regularly in vernal pools in spring. A male collected March 5, 1953 had been feeding on caddis fly larvae. Sometimes a pair will nest along intermittent streams—seldom successfully.

¹New species recorded since 1955.

Green-winged teal

(*Anas carolinensis*).¹ Casual winter migrant.

Recorded on the pond in Range Unit 9 on December 5, 1972 by Don A. Duncan.

Cinnamon teal

(*Anas cyanoptera*).¹ Casual winter migrant.

Several seen February 1965 on pond in Range Unit 9. Occasional birds seen on reservoir in Range Unit 9 during winters of 1970-72.

Blue-winged teal

(*Anas discors*). Vagrant.

A group was reported at the horse pasture dam March 8, 1937 by Ben Glading.

American widgeon

(*Mareca americana*).¹ Casual winter migrant.

Seen occasionally on reservoir during winters of 1970-72.

Wood duck

(*Aix sponsa*).¹ Permanent resident—1.

A pair nested at reservoir in Range Unit 9 during the spring of 1971. A brood was successfully hatched. Occasional birds seen at the reservoir during the year.

Gadwall

(*Anas strepera*).¹ Casual winter migrant.

Occasionally seen on reservoir in Range Unit 9 during winter of 1970-71.

Redhead

(*Aythya americana*). Casual winter migrant.

Five or six were seen on reservoir by Jay R. Bentley.

Ring-necked duck

(*Aythya collaris*). Casual winter migrant.

Six individuals were seen in March 1952. They were absent, as were nearly all ducks, the following season.

Greater scaup

(*Aythya marila*). Casual winter migrant.

A flock of 20 was seen on February 24, 1952.

Ruddy duck

(*Oxyura jamaicensis*). Casual.

One male was collected June 4, 1937.

Hooded merganser

(*Lophodytes cucullatus*). Casual winter migrant.

Three individuals were noted in February and March 1952. Several seen on ponds in 1960's.

Common merganser

(*Mergus merganser*). Casual winter migrant.

One flock of five was recorded February 5, 1952.

Turkey vulture

(*Cathartes aura teter*). Summer resident—1.

A nest was found in a rock outcrop May 22, 1951. Migrating flocks of more than 500 birds have roosted overnight in digger pines during September or October.

California condor

(*Gymnogyps californianus*). Casual.

A flock of six to nine individuals was seen August 30, 1950 (Cohen 1951). None has been seen since.

Sharp-shinned hawk

(*Accipiter straitus*). Winter resident—3.

This hawk was recorded between September 12 and April 4.

Cooper's hawk

(*Accipiter cooperii*). Permanent resident—3.

Habits of this species on the Experimental Range were studied by Fitch, Glading, and House (1946).

Red-tailed hawk (*Buteo jamaicensis*

calurus). Permanent resident—1.

This species is the most abundant raptor occurring on the Experimental Range. Its habits were reported in detail by Fitch, Swenson, and Tillotson (1946).

Rough-legged hawk

(*Buteo lagopus s. johannis*). Casual.

One was recorded on September 26, 1951, and another on March 20, 1952.

Golden eagle

(*Aquila chrysaetos*). Casual.

Fitch, Swenson, and Tillotson (1946) recorded it as frequent in the area. Don A. Duncan reported seeing a few each year during the 1960's. Several were sighted in 1971 and 1972. One was observed on April 12, 1973. And one was observed flying over Range Units 3-3 and 6-3 on April 20, 1973 by Frank Starkey and Thomas F. Newman.

¹ New species recorded since 1955.

Bald eagle

(*Haliaeetus leucocephalus*). Sporadic.

Recorded once by Fitch, Swenson, and Tillotson (1946). One was recorded during a snowstorm on January 27, 1957 by Robert F. Buttery. One was observed by Don A. Duncan December 27, 1970 in Range Unit 4-2. A mature individual was seen in Range Unit 10 by Duncan, Frank Starkey, and Thomas F. Newman on December 28, 1972.

Marsh hawk (*Circus cyaneus*). Casual.

One was recorded November 28, 1950. Don A. Duncan observed one in 1970 and one on April 24, 1971. Most sightings occur where bluffs meet the open valley.

Osprey (*Pandion haliaetus*).¹ Casual.

Don A. Duncan reports that a pair stayed at a neighbor's pond for several months in spring 1968. They flew over the Experimental Range occasionally. One was found dead, probably shot, under a snag in the lake.

Prairie falcon

(*Falco mexicanus*). Casual.

Seen October 6, 1951. Two were seen at the corals April 21, 1972. Arlene Wilkinson² recorded one on December 28, 1953.

Sparrow hawk

(*Falco sparverius*). Permanent resident—3.

J. T. Wright found a nest in a digger pine in 1937; another nest was found in a telephone pole March 28, 1953. Childs (1952) reports the taking of a kangaroo rat by a sparrow hawk.

California quail

(*Lophortyx c. californicus*).

Permanent resident—1.

This bird is the most abundant avian resident, nesting from May to mid-August. Much of the work serving as the basis for quail management in California was done by Ben Glading and others at the Experimental Range (Duncan 1968, 1971; Duncan and Shields 1966; Emlen and Glading 1938; Glading 1938a, 1938b, 1941; Glading, Biswell, and Smith 1940; Glading and Saarni 1944; Herman and Chatten

1943; Herman and Glading 1942; Herman, Jan-kieweiz, and Saarni 1942; Philpot, Howard, and Graham 1948; Shields and Duncan 1966). Much research has been done from 1960 to date on food habits and reproductive success. A cooperative study with California Department of Fish and Game and the University of California, Berkeley, was begun in 1971.

Chukar (*Alectoris graeca*).¹ Vagrant.

One seen in May 1972 by Don A. Duncan; probably a release from a neighboring ranch.

Turkey (*Meleagris gallopavo*).¹ Vagrant.

One was seen on April 19, 1972 in Range Unit 3-1 by Thomas F. Newman and Don A. Duncan. A single bird was seen on May 6, 1972 in Range Unit 3-2 by Duncan. The California Department of Fish and Game released wild turkey in the Raymond area about 6 miles away.

Peafowl (*Pavo cristatus*).¹ Vagrant.

Two adult females were seen July 7, 1971 by Stanley L. Anderson and Don A. Duncan.

Virginia rail (*Rallus limicola*). Casual.

One specimen has been taken.

American coot (*Fulica americana*). Casual.

Recorded in an owl pellet (Fitch 1947b). Seen occasionally on ponds during 1970-71.

Killdeer

(*Charadrius vociferus*). Permanent resident—2.

Nests of this species were found with four eggs in each on February 28, April 3, May 29, and June 1, 1952.

Common snipe

(*Capella gallinago*). Casual migrant.

One individual was observed twice in late March 1953.

Dunlin (*Erolia alpina*). Casual.

Observed by J. T. Wright in April 1937.

Band-tailed pigeon

(*Columba fasciata*). Sporadic winter visitant.

The numbers of this species were high in 1951. During 1952 and 1953 only an occasional flock was recorded in February and March. Abundant in some years when acorns are plentiful, such as winter of 1972-73.

¹New species recorded since 1955.

²Wilkinson, Arlene. *Birds of the foothill woodland community*. 1953. (Unpublished M.A. Thesis on file at California State University, Fresno.)

Mourning dove

(*Zenaidura macroura*). Permanent resident—1.

Very abundant in the fall when there is a good crop of turkey mullein (*Eromocarpus setigerus*). Ranch pond construction has greatly increased the use of foothill areas by doves.

Road-runner

(*Geococcyx californianus*). Permanent resident—3.

A covey of quail was seen "mobbing" one of these unusual birds July 31, 1952. Population has been down, but is apparently starting to recover. Thomas F. Newman and Stanley E. Westfall observed a road-runner drinking at a water trough in Range Unit 5-1 on August 31, 1972 and several were seen in the fall of 1972. One was seen January 5, 1973 in Range Unit 3-2 by Thomas F. Newman.

Barn owl

(*Tyto alba pratincola*). Permanent resident—3.

This ground feeding species, although not common, takes many pocket gophers for food.

Screech owl

(*Otus asio quercinus*). Permanent resident—2.

Heard frequently in the blue oaks on the Range.

Great horned owl

(*Bubo virginianus pacificus*).

Permanent resident—1.

A detailed account of the horned owl is provided by Fitch (1940, 1947b) and Howard (1958).

Pygmy owl

(*Glaucidium gnoma*).¹ Status undetermined.

Thomas F. Newman found one dead in a water trough November 8, 1971.

Long-eared owl

(*Asio otus*). Status undetermined.

A specimen was taken March 4, 1937.

Poorwill

(*Phalaenoptilus nuttallii*). Vagrant.

One was reported calling by Jay C. Quast in August 1949.

Common nighthawk

(*Chordeiles minor*). Casual.

Recorded in April, May, and October in small numbers.

Black swift (*Cypseloides niger*).

Vagrant.

One reported May 9, 1961 by Robert F. Buttery.

¹ New species recorded since 1955.

Anna's hummingbird

(*Calypte anna*). Permanent resident—3.

Observed January 20, 1957 and all winter of 1957; January 3, 1958 by Robert F. Buttery. Arlene Wilkinson² reported them present during March, April, and May during 1953. Present in small numbers year-round.

Rufous hummingbird

(*Selasphorus rufus*). Migrant.

Two have been recorded: April 1952 and March 1953.

Allen's hummingbird

(*Salasphorus sasin*). Migrant.

Several were seen in March 1953 and on March 23, 1959 by Robert F. Buttery.

Belted kingfisher (*Megaceryle alcyon*).

Resident-breeding status uncertain.

An occasional bird is seen at the reservoir.

Red-shafted flicker (*Colaptes cafer collaris*).

Permanent resident—2.

Resident birds are uncommon, but the red-shafted flicker is often seen in winter.

Acorn woodpecker (*Melanerpes formicivora bairdi*).

Permanent resident—1.

Very abundant and frequently observed. Acorn storing habits often damage buildings, power poles, and fence posts.

Lewis' woodpecker

(*Asyndesmus lewis*). Winter resident.

Often present during winter, but was not recorded in the 1952-53 season, although abundant a few hundred feet below the Experimental Range. Robert F. Buttery reports they were fairly common on the lower part of the range before digger pines were felled prior to a controlled burn. Don A. Duncan reports that the abundance increased during the 1960's, and a population stayed the fall and winter of 1970-71. In 1965 hundreds could be seen on a drive on Experimental Range roads.

Yellow-bellied sapsucker (*Sphyrapicus varius daggetti*).

Winter residents—2.

The sapsucker arrives as early as September 6 and it remains until late April.

²Wilkinson, Arlene. *Birds of the foothill woodland community*. 1953. (Unpublished M.A. Thesis on file at California State University, Fresno.)

Downy woodpecker

(*Dendrocopos pubescens*). Permanent resident—3.

Two have been recorded: July 26, 1952 and January 15, 1953.

Nuttall's woodpecker

(*Dendrocopos nuttallii*). Permanent resident—2.

A notably territorial species frequently seen in blue oaks and digger pines.

Western kingbird

(*Tyrannus verticalis*). Summer resident—1.

The kingbird arrives in late March and departs in September.

Ash-throated flycatcher

(*Myiarchus c. cinerascens*). Summer resident—1.

Found between mid-April and mid-September in small numbers.

Black phoebe (*Sayornis nigricans semiatra*).

Permanent resident—3.

Nests in culverts around headquarters and in Pasture 1.

Say's phoebe (*Sayornis s. saya*).

Winter resident—2.

The Say's phoebe arrives in mid-September and leaves in mid-March. It roosts commonly during the winter in protected places around the headquarters building, where 10 were banded.

Hammond's flycatcher

(*Empidonax hammondi*). Migrant.

Specimens were taken April 15, 19, and 28, 1937.

Gray flycatcher

(*Empidonax wrightii*). Migrant.

Specimens were taken April 19 and 21, 1937. Observations of *Empidonax* flycatchers since 1951 have been few, and the birds remain quiet, making specific identification impossible.

Western wood pewee

(*Contopus sordidulus*). Summer resident—2.

Resident status has not been fully determined. Arlene Wilkinson² reported sighting a few during December 1953.

Olive-sided flycatcher

(*Nuttallornis borealis*). Migrant.

A few have been seen during April and May.

Horned lark (*Eremophila alpestris*). Casual.

Recorded once in a drift trap.

Violet-green swallow (*Tachycineta thalassina lepida*). Summer resident—1.

This swallow arrives around March 1 and leaves by early October. It nests in woodpecker holes in blue oaks and digger pines.

Tree swallow (*Iridoprocne bicolor*). Migrant.

J. T. Wright considered tree swallows to be resident in 1937. None has been observed since 1951.

Rough-winged swallow

(*Stelgidopteryx ruficollis*). Casual.

One was observed April 26, 1953.

Barn swallow (*Hirundo rustica erythrogaster*).

Summer resident—3.

A nest was found in a culvert under the main road July 5, 1952.

Cliff swallow (*Pentochelidon albifrons*).

Summer resident—3.

One was observed May 13, 1953. A pair successfully nested in a tile vent of headquarters building in May 1958. Also observed May 11, 1961 by Robert F. Buttery.

Purple martin (*Progne subis*). Casual.

A flock was recorded on May 22, 1948.

Steller's jay (*Cyanocitta stelleri*).¹

Sporadic winter visitant.

One seen for two days in the winter of 1966 by Don A. Duncan. One seen October 29, 1972 by Frank S. Starkey. One seen December 2, 1972 by Thomas F. Newman and Don A. Duncan. Three seen December 3, 1972 by Duncan in Range Unit 9. Multiple sightings during December 1972 in Range Units 2, 9, and 10. Last recorded sighting of these overwintering birds was on April 20, 1973 by Bill Webb and Thomas F. Newman in Range Unit 9.

Scrub jay (*Alphelocoma coerulescens superciliosa*). Permanent resident—1.

These birds are perhaps the most commonly seen

²Wilkinson, Arlene. *Birds of the foothill woodland community*. 1953. (Unpublished M.A. Thesis on file at California State University, Fresno.)

¹New species recorded since 1955.

birds on the Experimental Range. Young birds have been found in the nest as early as March 31, in 1952. Arlene Wilkinson² has described the nesting activity of scrub jays.

Common raven (*Corvus corax*).

Permanent resident—2.

First two sightings were on April 21, 1952 and April 1, 1953. Pairs and singles have been seen on many occasions 1965 to 1972.

Clark's nutcracker

(*Nucifraga columbiana*). Casual.

One observed during the period September 15 to October 28, 1950. Conditions in the high country brought many unusual records of this species over California during that year.

Plain titmouse (*Parus i. inornatus*).

Permanent resident—1.

The titmouse is a common species in blue oaks, but it is rarely heard calling after nesting starts in March.

Common bushtit (*Psaltiriparus minimus californicus*). Permanent resident—1.

Most commonly seen in association with evergreen plant species such as *Ceanothus* and live oaks.

White-breasted nuthatch (*Sitta carolinensis aculeata*). Permanent resident—2.

This bird has essentially the same ecological requirements as the titmouse.

Brown creeper (*Certhia familiaris zelotes*).

Permanent resident—3.

Several have been recorded: November 30, 1951; January 15, and February 5, 1952; December 5 to April 18, 1953.

Wrentit (*Chamaea fasciata henshawi*).

Permanent resident—3.

Nesting status uncertain. A specimen was collected March 31, 1937.

House wren (*Troglodytes aedon parkmanii*).

Summer resident—3.

Presence of a few house wrens in May and June in suitable breeding area suggests that breeding does occur.

²Wilkinson, Arlene. *Birds of the foothill woodland community*. 1953. (Unpublished M.A. Thesis on file at California State University, Fresno.)

Bewick's wren (*Thryomanes bewickii drymoecus*). Permanent resident—2.

Regularly found in the brush areas of the Range.

Canyon wren (*Catherpes mexicanus conspersus*). Permanent resident—2.

Found commonly in the rocky canyons.

Rock wren (*Salpinctes o. obsoletus*).

Winter resident—2.

Seen occasionally in winter.

Mockingbird (*Mimus polyglottos leucopterus*).

Winter resident—3.

About 10 individuals were present around headquarters during the period October 1952 to March 1953, but the mockingbird is rare over most of the Experimental Range. The numbers around headquarters have declined.

California thrasher (*Toxostoma r. redivivum*).

Permanent residents—2.

This secretive species is heard singing commonly in February and March in brushy areas. One observed October 20, 1964 by Crystal A. Burns and Juanita Anderson. Arlene Wilkinson² reported one on February 15, 1953.

Robin (*Turdus migratorius propinquus*).

Winter resident—2.

Generally arrives in late December and leaves in early April, but the actual dates may be 1 to 2 months earlier or later.

Varied thrush (*Ixoreus naevius*).

Sporadic winter visitant.

One was recorded December 31, 1951. Many seen during December 1972 by Don A. Duncan and Thomas F. Newman.

Hermit thrush

(*Hylocichla guttata*). Migrant.

Seen between January 22 and April 18, 1952, but was not present the following year. Seen February 10, 1957 and January 19, 1958 by Robert F. Buttery. One taken away from a Cooper's hawk December 28, 1972.

Swainson's thrush

(*Hylocichla u. ustulata*). Status undetermined.

One was recorded May 31, 1953.

Western bluebird (*Sialia mexicana occidentalis*). Permanent resident—3.

Nests in holes in blue oaks. In winter, flocks of 10 to 20 individuals are common.

Mountain bluebird
(*Sialia currucoides*). Sporadic.

One was collected from a flock of six on December 31, 1951. Don A. Duncan saw a flock of four April 25, 1971.

Blue-gray gnatcatcher (*Polioptila caerulea amoenissima*). Summer resident—2.

Recorded only in the natural area and in April and May.

Ruby-crowned kinglet (*Regulus calendula cineraceus*). Winter resident—2.

The kinglet is seen commonly in winter, feeding in the foliage of oaks.

Water pipit (*Anthus spinoletta*). Casual.

Two have been recorded; April 9, 1937, and March 30, 1952.

Cedar waxwing
(*Bombycilla cedrorum*). Casual winter visitant.

Small flocks are occasionally seen between October and May.

Phainopepla (*Phainopepla nitens lepida*). Summer resident—2

Generally arrives in May and leaves in late fall. Nesting is underway by June 1. Commonly seen during the spring and summer. Thomas F. Newman saw a male in Range Unit 8 on November 11, 1972. Early arrival observed February 14, 1957 in headquarters area by Robert F. Buttery.

Loggerhead shrike (*Lanius ludovicianus gambeli*). Permanent resident—3.

Nesting status uncertain. The shrike is recorded occasionally in the open areas. One observed January 10, 1957 by Robert F. Buttery and May 10, 1973 by Don A. Duncan.

Starling
(*Sturnus vulgaris*).¹ Permanent resident—3.

Don A. Duncan reports a few were present in the late 1960's, by 1970 there were several nesting pairs

on the Experimental Range. Numbers seem to be increasing substantially.

Solitary vireo (*Vireo solitarius*). Migrant.
One was seen April 18, 1952.

Warbling vireo (*Vireo gilvus*). Casual.
Two were recorded: April 18 and May 15, 1952.

Orange-crowned warbler
(*Vermivora celata*). Casual.
One was seen April 18, 1952.

Nashville warbler
(*Vermivora ruficapilla*). Migrant.
Two were recorded: April 18 and September 5, 1952.

Yellow warbler
(*Dendroica petechia*). Migrant.
Heard regularly between April 20 and June 4.

Myrtle warbler
(*Dendroica coronata*). Migrant.
One was collected on March 2, 1937.

Audubon's warbler
(*Dendroica a. auduboni*). Winter resident—1.
This warbler is present in numbers from October to May.

Black-throated gray warbler
(*Dendroica nigrescens*). Migrant.
Several were seen in April 1952.

Townsend's warbler
(*Dendroica townsendi*). Migrant.
Several were seen in April and May, 1951.

Hermit warbler
(*Dendroica occidentalis*). Migrant.
One was recorded April 23, 1952.

Yellow-throat
(*Geothlypis trichas*). Vagrant.
One was collected April 7, 1952.

Yellow-breasted chat
(*Icterus virens auricollis*). Migrant.
One was collected May 10, 1937.

Wilson's warbler
(*Wilsonia pusilla chryseola*). Migrant.
Four individuals were seen on April 30, 1952.

¹ New species recorded since 1955.

Robert F. Buttery reported two on September 15, 1958. One female seen at headquarters by Don A. Duncan and Jack N. Reppert, September 16, 1960. One male seen at headquarters on September 11, 1972.

House sparrow

(*Passer d. domesticus*). Permanent resident—2.

A few individuals are resident around headquarters. In spring 1953, house sparrows nesting in woodpecker holes in blue oaks increased noticeably, a possible result of woodpecker control in that area the previous season. Starlings may be competing for available nesting holes; house sparrow numbers down; starlings, up.

Western meadowlark

(*Sturnella neglecta*). Permanent resident—2.

Abundant in winter but nests sparingly in summer.

Red-winged blackbird

(*Agelaius phoeniceus*). Summer resident—2.

Arrives in late February and leaves in September. Most of red-winged blackbirds are found in swale near headquarters.

Bullock's oriole

(*Icterus bullockii*). Summer resident—1.

The oriole arrives in April and it leaves by mid-August. It nests in blue oaks.

Brewer's blackbird

(*Euphagus cyanocephalus*). Permanent resident—2.

Most abundant in the headquarters area, where breeding activity starts in March. Nests are found in mistletoe, blue oaks, and in vines on various buildings during April and May.

Brown-headed cowbird

(*Molothrus ater*). Summer resident—3.

Occasional individuals are heard calling from February to June.

Western tanager

(*Piranaga ludoviciana*). Casual.

Observed May 15, July 31, and September 16, 1952.

Black-headed grosbeak (*Pheucticus melanocephalus maculatus*).

Recorded between April 10 and August 8, 1952. Stanely E. Westfall and Thomas F. Newman saw two

females in a buckeye in the headquarters area on August 8, 1973.

Lazuli bunting

(*Passerina amoena*). Casual.

Recorded on April 18, 1952.

Purple finch (*Carpodacus purpureus californicus*).

Seen occasionally during the winter of 1951-52. Reported February 16, 1958 by Robert F. Buttery. Arlene Wilkinson² recorded a few from March 15 to April 19, 1953.

House finch (*Carpodacus mexicanus frontalis*).

The linnet is found mainly in the inhabited area of the Range where it nests from May to July.

Pine siskin (*Spinus pinus*).

One flock was observed in May 1952.

Lesser goldfinch

(*Spinus psaltria*). Casual.

Three were collected March 18, 1937. One observed in headquarters area on February 15, 1957 by Robert F. Buttery. Two seen May 2, 1953. Several flocks sighted during December 1972.

Lawrence's goldfinch

(*Spinus lawrencei*). Permanent resident—3.

Occasional groups of these birds are seen over the Range.

Green-tailed towhee

(*Chlorura chlorura*). Casual.

One was collected April 29, 1937.

Rufous-sided towhee

(*Pipilo erythrophthalmus*). Winter resident—1.

Arrives in late September and leaves in early April.

Brown towhee

(*Pipilo fescus carolae*). Permanent resident—1.

In 1952 nest building began in early April. Arlene Wilkinson² reported nesting in March 1953.

²Wilkinson, Arlene. *Birds of the foothill woodland community*. 1953. (Unpublished M.A. Thesis on file at California State University, Fresno.)

Savannah sparrow (*Passervulus sandwichensis nevadensis*). Vagrant.

One was collected May 13, 1937, and another October 21, 1952. One recorded by Wilkinson² on December 14, 1953.

Vesper sparrow

(*Pooecetes gramineus*). Casual.

One was collected October 12, 1951.

Lark sparrow (*Chondestes grammacus strigatus, strigatus*). Permanent resident—2.

Sparingly resident over the Range.

Rufous-crowned sparrow

(*Aimophila r. ruficeps*). Permanent resident—3.

Noted only on the walls of the big canyon below headquarters. J. T. Wright believed their distribution dependent on the deer weed (*Lotus scoparius*). But Arlene Wilkinson² observed them foraging in grassy areas, in 1953.

Slate-colored junco

(*Junco hyemalis*). Casual.

One was seen December 31, 1951.

Oregon junco

(*Junco oreganus thurberi*). Winter resident—1.

This junco arrives in mid-October and it leaves in April.

Chipping sparrow

(*Spizella passerina arizonae*). Migrant.

Has been recorded in April, May, September, and October in small numbers.

Gambel white-crowned sparrow

(*Zonotrichia leucophrys gambeli*).

Winter resident—1.

Arrives in late September and leaves in late April. Mixed flocks of this species with golden-crowned sparrows and Oregon juncos are a common sight in winter.

Golden-crowned sparrow

(*Zonotrichia antricapilla*). Winter resident—1.

The golden-crowned sparrow arrives about a week later than the white-crowned but departs about the same time.

Lincoln's sparrow

(*Melospiza lincolni*). Winter resident-3.

A few are present along the swales from early October to April.

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The Station's range-wildlife environmental research unit, headquartered at Fresno, California, is developing the scientific base for multiple-use management of central California ecosystems. This report adds a facet of knowledge for the ecosystem of the Sierra Nevada foothills.

EDITOR'S NOTE: *General Technical Report* is a new series of Forest Service research publications that complements the three existing series: *Research Paper*, *Research Note*, and *Resource Bulletin*. The General Technical Report series serves as an outlet for information of a technical nature but not necessarily the product of a specific piece of original research or resource survey.



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Can Southern California Wildland Conflagrations be Stopped ?

Clive M. Countryman

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Countryman, Clive M.

1974. **Can southern California wildland conflagrations be stopped?**
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11 p. (USDA Forest Serv. Gen. Tech. Rep. PSW-7)

In southern California, many fires start and burn under conditions that permit their control with little burned acreage and fire damage. In contrast, under other conditions of weather and topography, on a small group of fires, control effort is relatively ineffective; they become large and destructive. A major reason for these "conflagration fires" is the extreme difficulty of stopping the head of a hot, fast-running fire in dry fuels and strong winds. No radically new concept of suppression can be anticipated. The best prospect for alleviation of the problem is modification of the vegetation to reduce fuel energy output. In a fuel-type mosaic containing large areas of light fuels, where conventional suppression will be effective, potential conflagrations could be brought under control while relatively small. Creation of the fuel-type mosaic will require coordinated area-by-area planning and a variety of techniques.

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Retrieval Terms: fire management; southern California; high intensity fires; flash fuels; fuel modification; chaparral fires.

The 1970 fire season was one of the worst in California's long history of disastrous fire seasons—certainly the worst in recent years. More than 500,000 acres of watershed and timber were burned, most of them in the short period between September 25 and October 4. The loss of 16 lives can be attributed to the fire activity. More than 700 homes and other structures were burned, and fire damage and suppression costs have been estimated at \$233,000,000. The damages will continue to mount, since the threat of flood and erosion will continue until protective vegetative cover returns to the denuded watersheds—in some areas this will take many years.

California does not have an exclusive corner on the large-scale, high-intensity fires often called conflagrations or conflagration fires. In 1970, several such fires in Washington State destroyed extensive areas of timber. The Trapper Peak and Sundance fires burned in Idaho and Montana in 1967. Other regions also have large wildland fires from time to time. But conflagrations in other areas are usually infrequent, with several to many years elapsing between "bad" seasons. In California, large and devastating fires occur nearly every year. Statistics compiled by the U.S. Forest Service indicate that the California region consistently accounts for about 42 percent of the burned area and 55 percent of the reported damage in the National Forests within the contiguous United States. Most of the California conflagrations occur in the southern half of the State, the area south of the Tehachapi Mountains being particularly susceptible.

The gravity of the southern California fire problem has long been recognized. But despite years of effort by control agencies and research, the fires continue to occur with alarming regularity, and damages and suppression costs continue to grow.

This paper describes the causes and characteristics of the conflagration fires in southern California, and evaluates present and proposed efforts to find a solution. A unified program aimed at the one element of conflagration fires that can be practicably modified—the fuel—is outlined.

THE FIRE PROBLEM

Climate, Fuels, Topography, and People Create Fire Problem

Why are there so many fires in southern California? Primarily because the Mediterranean climate and a distinctive complex of topography and fuel create conditions favorable to major fires during every month of the year. The winters are mild, with infrequent short rainy periods. A long period without rain often extends from early spring to late fall or early winter. Steep and rugged mountains, cut by numerous canyons, border most of the major cities. Much of the mountain land is covered with a dense growth of flammable chaparral shrubs, such as chamise, manzanita, ceanothus, and scrub oak. On the lower slopes and foothills, this heavy growth gives way to lighter, but extremely flammable vegetation, such as sage, buckwheat, and various grasses and forbs. Some of the higher ridges are covered with conifers—mostly pine—interspersed with chaparral and grass. During the late winter and early spring growing season, the vegetation usually contains large amounts of moisture—providing there has been enough rain to start growth at all. But with the onset of the long rainless season, the annual plants die, and the shrubs lose much of their moisture. By September, some of the living plants, such as chamise, can be ignited with a match, and the dead and dry annuals can be touched off by a spark. After a fire, many of the plant species sprout prolifically, and others regenerate from seed left in the soil. Within 10 to 20 years, enough standing fuel has developed and dead material accumulated to permit the area to burn hot and fast again.

The great population influx into southern California has vastly complicated the fire hazard created by natural conditions. Residential subdivisions and individual houses have been pushing farther and farther into the mountains. Houses are often perched on ledges bulldozed into the steep slopes, or are crowded on sharp ridges and in narrow canyons. The conifer-covered ridges do not escape this influx—wherever

private land is available, homes and resort communities abound. Campgrounds, picnic areas, and organization camps dot the public lands in these areas. The result is a fire control problem probably without parallel elsewhere in the world.

Relatively Few Fires Become Conflagrations

All fires that start in California do not have the potential for becoming large and damaging. Local variations in weather, fuels, topography, and the location of the fire may limit the rate and extent of fire spread, and create wide variations in the difficulty of fire control. And wildland fire control forces are highly effective. As a result, the vast majority of fires are controlled while still small. In the 5-year period ending in 1968, less than 1 percent of the fires on California National Forests became 300 acres or larger, and less than 4 percent larger than 100 acres. Even during the unusually severe conditions between September 25 and October 4, 1970, less than 5 percent of the fires reached 300 acres or more. It is the few fires that escape early control, however, that do most of the damage—80 to 90 percent of the total. And it is these fires that must be stopped if the southern California conflagration problem is to be solved.

Conflagrations Are Most Frequent During Santa Ana Winds

During most of the year, southern California has westerly winds and a marine climate. Hot days can occur almost any time during the year, but are most frequent during the summer and early fall. Because of the marine influence, the air is seldom excessively dry. Overcast days even in summer are not unusual. Relative humidity, and hence fuel moisture also, usually reach fairly high levels at night. Under these conditions, fires can usually be controlled when small—most within a short time after they start. Occasionally, however, when the weather is particularly dry or windy, a fire will escape early control and become large and damaging. Such fires are relatively rare under the marine climate, however.

Most of the large fires in southern California occur when the marine airflow is replaced by the föehn-type Santa Ana winds. Originating as cold, dry air high in the troposphere, these winds sweep down from the Great Basin area, warming by compression and becoming more dry as they come. Reaching the ground near the desert rim, they roar down the mountain slopes and canyons to the sea. Wind speeds may reach 100 miles per hour in exposed areas, and relative humidity frequently approaches the vanishing point. The rough, broken topography and high wind

speeds create highly turbulent air flow in the many canyons. Wind direction in these areas may switch 180 degrees and back again in a few seconds.

The Santa Ana “season” ordinarily starts in middle or late September. Santa Ana periods increase in frequency during October and November and begin to taper off in December. A second peak in Santa Ana frequency may occur in March (*table 1*).

Table 1—Number of Santa Ana periods by months southern California 1951-60

Month	Frequency	Average days
September	11	4.4
October	19	4.5
November	26	5.0
December	18	3.7
January	7	1.7
February	10	1.9
March	17	2.5
April	8	1.8
May	7	1.4
June	4	4.5
July	2	2.5
August	0	0

Santa Ana periods that occur in fall and early winter, before the rains begin, generally create the greatest conflagration hazard, as the moisture content of both dead and living fuel is then likely to be at its lowest ebb. Because of the rapid drying of all fuels under Santa Ana conditions, however, major fires can occur later in the year, particularly when winter rainfall is light. For example, three fires starting in the mountains at the edge of Los Angeles during a Santa Ana on March 16, 1964, burned a total of 11,650 acres, destroyed 20 houses, and severely damaged 10 others.

The Santa Ana winds usually follow a typical pattern of development and regression. In their initial phase, the strong winds reach the ground suddenly and follow the terrain configurations. The temperature is often high, and the relative humidity remains low both day and night. With these conditions, living fuels become parched and the dead fuels quickly become tinder dry. Because the dry Santa Ana air is relatively heavier than the more moist marine air, the winds tend to “channel,” flowing through the mountain passes and down the main drainages. Between these areas the wind is often light. The initial phase of the Santa Ana can usually be measured in hours, but occasionally may last 2 or 3 days.

When the area on the lee side of the mountains fills with the dry, heavy air, and the offshore pressure gradient begins to weaken, the strong Santa Ana

winds begin to lift above the ground, bringing some moderation in the wind speed at the surface. This process begins at low elevations first, and then progresses upward until only the higher slopes and ridges have the strong winds. The high-speed winds may surface again intermittently, particularly at night. Where winds are light, thermal up-slope and up-canyon airflow will develop during this phase of the Santa Ana, as it normally does under the marine climate. The air remains extremely dry, however, and the wind over the ridges is opposite in direction to marine airflow. This phase of the Santa Ana lasts for varying times—usually 2 or 3 days, but sometimes a week or more.

As the offshore gradient continues to weaken, the marine air begins to intrude again, first along the coast, and then pushing further inland as onshore pressure gradient builds. Although burning conditions in this phase of a Santa Ana have been greatly moderated, it is a period of high hazard for firefighters. In the area where the marine and Santa Ana air meet, the wind can be highly variable in speed and direction. The fuels remain extremely dry, and fires can flare up quickly and move rapidly, particularly in rough terrain. Most firefighting accidents in southern California occur during this phase of a Santa Ana. Finally the Santa Ana winds cease, the fuels begin to pick up moisture from the marine air, and normal weather conditions again prevail.

Suppression of Santa Ana Fires is Difficult

Controlling a fire that starts in a wind affected area during the initial phase of a Santa Ana is an enormously difficult task. The dry fuels permit fires to start easily and build up quickly. Within a few minutes spot fires begin to appear. The fire is then so widespread that it is usually beyond hope of control by initial attack forces. Driven by the strong wind, the fire spreads rapidly. It is not unusual for a fully developed fire in chaparral to enlarge at the rate of 4 to 6 square miles per hour during the initial phase of a Santa Ana. Spot fires are numerous, sometimes up to a mile ahead of the main fire and occasionally as much as 4 miles. Because of the spot fires, rough topography, and turbulent wind, the fire front is often extremely ragged—the effective fire front may be very deep, with rapidly enlarging spot fires and moving tongues of fire as much as a mile ahead of the main body of fire. The smoke from the fire is held close to the ground by the wind, cutting visibility to near zero in many areas.

As the fire grows, so does the difficulty of controlling it. Barriers that could have been used by firefighting crews to make a stand against a fire under the

marine climate become ineffective as a hail of burning embers is driven into the unburned fuel ahead of the fire—Santa Ana fires have been known to cross freeways without slowing. Long distance spotting becomes more prevalent as the fire enlarges. Dense smoke, and blowing sand, dust, and ashes make control work slow and arduous. Because of the rapid fire spread, numerous spot fires, poor visibility, and the large and deep fire front, the hazard to the firefighting force is extreme. Some of the usual firefighting tools and techniques also become ineffective.

Thus, the fire often continues to spread rapidly with the wind until the fire head runs out of fuel or the initial phase of the Santa Ana ends. But even then, the fire is not over. Control forces are still faced with the monumental task of constructing many miles of fireline to stop the lateral and rearward spread of the flames. If the wind continues, additional rapid fire runs, parallel to the initial run, may occur. Because of the rugged topography, access to the fire edge is nearly impossible in many places, and feasible locations for control lines are few and far between. Also, considerable time is required to construct effective control lines. As a result, the fire may double or even triple in size during the final control operations, even though burning conditions have moderated.

Usually, little can be done to stop the head of a fire during the initial phase of a Santa Ana, but effective work is often possible at the rear and much of the flanks of the fire. Because of the strong wind, large sections of the rear of the fire oftentimes go out, and frequently the flanks are relatively free of many of the problems that plague firefighters at the head of the fire. Thus, it would appear that if firefighting efforts were concentrated on the rear and flanks of the fire, control could be effected soon after the head of the fire stops. And this technique is frequently used in other areas where fires burn under strong winds. Unfortunately, however, the "people" problem often precludes the effective use of this strategy in southern California. In this area it is now unlikely that a fire can become large without homes, communities, and various other improvements being in its path. Because of this threat, it is frequently necessary to divert a large part of the available control force to the evacuation of people and the protection of structures and improvements. Often only token effort can be made toward control of the rear and flanks of the fire until the fire head stops. This problem becomes particularly acute when several major fires are burning at once and fire control forces are thinly spread.

FIRE CONTROL AS A SOLUTION

Much effort has been devoted to the abatement of the conflagration fire problem through improved fire control, and further endeavors in this area are being made or have been proposed. They include fire prevention activities, development of organizational structures and procedures for multifire and multi-agency fire suppression, increases in fire control forces and their efficiency, and improvements in fire-fighting techniques and equipment. Over the years, substantial increases in the effectiveness and efficiency of fire control operations in general have been achieved. No apparent drop in the number of conflagration fires has resulted, however, and the economic and human losses directly attributable to these fires continue to mount. There are several reasons for this condition.

Fire Prevention Has Limited Value

Fire prevention has received considerable attention as a possible means of eliminating or reducing the number of conflagration fires; obviously a fire that does not start will not have to be controlled. During the critical fire weather period of September 25 to October 5, 1970, the fire control agencies greatly intensified their fire prevention efforts. This action undoubtedly prevented many fires that would otherwise have further overloaded the fire control forces. But fire prevention programs appear to have little effect on those indifferent to the consequences of careless use of fire and fire starting agents. Arson fires are not susceptible to fire prevention programs, and neither are accidental fires such as those caused by motorized vehicle and other equipment accidents. Despite intensive fire prevention in 1970, the number of fire starts set a record.

All fires do not have conflagration potential; fires starting in some areas and from some causes are more likely than others to become conflagrations. Although fire prevention programs may reduce the total number of fire starts, even the best of fire prevention is not likely to significantly affect the number of fire starts that can become conflagrations.

In one area, however, fire prevention action could have significant impact. In California during 1970, about 55 percent of the burned area resulted from fires started by powerlines. In southern California, the figure was 68 percent, and included some of the most devastating fires. Although these 1970 figures were probably higher than normal, powerlines are known to be consistently a major cause of conflagration fires. Usually caused by strong winds, most such

fires start in extreme fire weather, and often in exposed areas of difficult access. Almost all powerline fires are started by secondary or "feeder" lines, not the major transmission systems. New types of conductors and techniques to put these powerlines underground have been developed. Application of this technology could virtually eliminate powerline fires and would substantially reduce the burned acreage in southern California—perhaps by as much as 50 percent.

Effect of Organizational Problems on Fire Size is Small

In southern California, several fire control agencies often must work together and provide mutual assistance during fire control operations on large fires and during multiple fire situations. The mutual aid between agencies in this area is perhaps the best anywhere in the nation, and it has been effectively used many times. It is probably inevitable, however, that some problems will arise between agencies that differ in organizational structure and power to act—especially during the confusion of multiple fires of major proportions.

Changes in fire control organization and procedures, particularly for critical fire situations, have been considered as a means of reducing the conflagration fire problem. Studies aimed at the development of sophisticated organizational structures and of techniques and procedures for highly centralized control of fire suppression operations have been undertaken. But interagency problems have been largely procedural and administrative. They have had little effect on the number of conflagration fires or the area that they burn. Thus, although more sophisticated organization and operational procedures may possibly effect more economic fire suppression, this line of attack does not appear to hold much promise for abatement of the conflagration fire problem.

Firefighting Techniques and Equipment Are Not Adequate

A fire that starts in an exposed area under a strong wind and dry fuel conditions, and with extensive areas of dense chaparral ahead of it, has a high probability of becoming a major fire unless it is suppressed almost immediately. Most chaparral fuels have nearly ideal characteristics for rapid combustion under dry and windy conditions, and the heat energy produced by a large and rapidly moving fire is tremendous. For example, a fire enlarging at the rate of 4 square miles per hour will produce 400 to 800 *billion* Btu's of heat per hour—about the same as burning 3 to 6 million

gallons of gasoline. And the greatest heat production is at the head of the fire. Because of the enormous energy output of an intense chaparral fire, present fire suppression methods and equipment are generally ineffective in stopping the head of a hot, fast-running fire in a strong wind. *This is the primary problem in the control of conflagration fires.*

Fire suppression methods have not changed basically since organized fire control began; equipment and techniques already in use have been improved and modified. Thus, bulldozers and other mechanical equipment are now used for much of the firebreak construction that was formally done manually, but firebreaks still remain the basic fire control method. Fire tankers and portable pumps have replaced the bucket brigade, and these have been supplemented with aerial delivery of water and fire retardants. Chemical retardants have been used in fire suppression since ancient times, but today better formulations and delivery methods have made their use more widespread.

Further improvement in firefighting techniques and equipment has been strongly supported in the search for an answer to conflagration fires. For example, soon after the 1970 fire disaster, the suggestion was made that massive air attack with fire retardants would provide quick control of conflagration fires. Over-all, however, the potential for "victory through air power" does not appear bright. The use of air tankers in the conditions in which conflagration fires burn is beset with difficulties. The hazard of low-level flying in rough terrain and turbulent winds may often preclude the use of aircraft at all. Air tankers do not provide an efficient method of retardant application; a sizable part of the retardant delivered is wasted—even under favorable conditions. And on the many spot fires and deep ragged front of a conflagration fire, delivery of extremely large volumes of fire retardants or water is required for any significant effect on fire behavior.

The effectiveness of fire retardants also decreases rapidly as fire intensity increases. Fire retardants are just that; they can be used to retard or slow a fire, but seldom extinguish it even under moderate burning conditions. It is essential that fire crews and equipment be able to work on the fire edge very soon after the retardant is applied if fire spread is to be stopped and the retardant drop is to be of any value. In conflagration fires, the opportunities to do so are usually limited to the flanks and rear of the fire because of difficult access and the extreme hazard at the head of the fire. Like other fire control techniques, air attack is stymied by the nature of the

conflagration fire and the conditions under which it burns.

Quick control of conflagration fires will probably require a radically new concept or technique in fire suppression. Such a breakthrough is not imminent, and it is improbable that one will appear soon. Suppression of conflagration fires does not appear amenable to solution with present technology.

Increased Fire Control Force Is Only a Partial Answer

Public wildland firefighting forces in southern California are probably the best of their kind in the world. Well trained and well led, and with a large amount of generally good equipment, they do an extraordinary job of suppressing fires and protecting property in difficult and hazardous situations. Without a firefighting force of this quality, losses from wildland fires would be vastly greater. But higher wages, greater operating and equipment costs, and appropriations that have not kept pace with these rising costs, are resulting in erosion of the strength and quality of public firefighting forces. Highly trained and experienced initial attack crews are becoming smaller or fewer in number. Some firefighting equipment cannot be fully manned, or cannot be used at all because of lack of manpower. The effect of this shrinking firefighting capability is felt most when critical fire weather and numerous fires occur over wide areas. When this happens there are not enough fire crews and equipment to handle the situation, and some fires become large that otherwise could have been stopped when small.

On the National Forests, the manpower problem has recently been ameliorated to some extent by increased authorization to use emergency firefighting funds during the fire season. But this must be considered a stop-gap measure—it does not provide the cadre of well trained and experienced firemen needed to direct season personnel and to insure safety and efficiency in firefighting.

Since present firefighting techniques are not generally effective in stopping the head of a conflagration fire, most of the effect of strengthened firefighting resources can be expected for non-conflagration situations. And fires under such conditions account for only 10 to 20 percent of the burned acreage. The impact on conflagration fires is not likely to be great. Many of the fires that start during Santa Ana and other severe fire weather are beyond hope of early control before firefighting forces can reach them—some before they are discovered—because of rapid spread, difficult access, or both. Under these condi-

tions, it simply is not economically feasible to have enough crews and equipment to stop all fires immediately after they start; the protected area is too large, the access too difficult, and the number of days during the fire season they are really needed in large numbers too few. While augmented fire control resources can ease the strain on firefighting agencies, reduce the number of fires and burned area for non-conflagration situations, and possibly effect earlier control of some conflagrations, the final answer to the conflagration fire problem is not likely to be found in more men and equipment alone.

A SOLUTION THROUGH FUEL MODIFICATION

If conflagration fires cannot be prevented from starting, and cannot be controlled before becoming large, must such fires be accepted as inevitable in southern California? I think not. The behavior of wildland fire is determined primarily by the weather, the topography, and the fuel. Little can be done about weather or topography. But wildland fuels, which supply the energy that makes some fires uncontrollable, are subject to modification and management. Limited fuel modification is, in fact, the basic principle of most control methods now in use. Depriving a fire of continued energy by removing all of the fuel in a band or firebreak around the fire, or putting water and chemicals on the fuel so that it will burn slowly or not at all, is fuel modification.

People have been changing the characteristics of vegetation as a fuel, intentionally and unintentionally, since prehistoric times. World-wide, vast areas have been cleared of native vegetation to provide farming and grazing lands, and sites for cities. Today, road construction, timber harvesting, silvicultural practices, grazing use, watershed development, recreational use, wildlife management practices—all result in modification of wildland fuels. In some areas, man-made air pollution has altered the vegetation and added to the amount of high flammable dead material. Man-caused fires quickly change the vegetation, and repeated fires may effect long-term changes in the fuel characteristics. Fire prevention and quick control of fire in areas where fires have occurred naturally in the past can result in the build-up of flammable vegetation that makes fires more intense and damaging when they do occur.

What kind of fuel modification is needed to stop southern California conflagration fires? The crux of the problem is the high energy output of chaparral fuels in extreme burning conditions. When a fire reaches an extensive area of low fuel loading, or slow-

burning fuel, or where the chaparral is interspersed with such fuel, the energy output drops over the fire front or at least many segments of it. Fire suppression methods then again become effective along much of the fire front, and firefighting forces can safely concentrate effort on the few relatively high-intensity sections and can take quick advantage of lulls in burning conditions. *What is needed then, is to create a fuel complex whose energy output even in the worst burning conditions is low enough to permit firefighting forces to contain the fire.*

Fuel modification is an accepted practice to reduce fire hazard and to aid in fire control. In timber areas, debris left from logging and silvicultural treatments is often reduced by burning or mechanical treatment. Prescribed fire is used in forest stands in the southern United States and some parts of the West to reduce the amount of fuel. In some regions, extensive areas of brush have been converted to grass or timber.

Although some fire control experts have long recognized the extensive areas of heavy chaparral as the primary cause of southern California's conflagration problem, no comprehensive plan has been put forth to reduce the hazard through extensive fuel modification and management. The disastrous 1970 fire season, however, and the growing realization that further large increases in fire control and fire prevention may not be helpful, have focused attention on fuel modification and management as a solution. Several approaches have been proposed or undertaken.

Rotational Burning Creates a Mosaic of Age Classes

Rotational burning is one method of fuel modification that has recently been strongly recommended for southern California. After a wildfire, chaparral does not burn easily again until the shrubs have regrown and dead fuel has accumulated. This regrowth may require 10 to 20 years or more, depending on the weather, soils, and intensity of the wildfire. In an area that has been subject to numerous fires over a period of years, the chaparral tends to appear in a mosaic of age classes, some parts of the mosaic not having sufficient fuel to support an intensive fire. If the mosaic contains enough areas of young chaparral and these areas are favorably distributed, conflagration fires are unlikely, as the large expanses of heavy fuels needed for such fires are lacking. Under the rotational burning concept, the mosaic of age classes would be artificially created by intentionally burning portions of the area each year under conditions in which a fire can be controlled and confined to a de-

sired size. The mosaic is to be maintained by repeated burning at intervals sufficiently short to prevent accumulations of highly flammable material.

This general technique has been successfully applied for many years in the pine timber stands of the Southern States, where low intensity fires are used at intervals to remove accumulated dead material and unwanted understory vegetation. It has also been extensively applied in the eucalyptus forests of Australia.

But chaparral stands are not the same as timber stands. Although rotational burning is a valuable technique for fuel modification in the areas for which it was developed, its application to southern California chaparral presents certain problems.

Adverse Effects

Southern California chaparral can become flammable enough to burn intensely within 20 years after a wildfire. Hence, for rotational burning to be effective, the interval between prescribed burns must be short—perhaps 15 years or less. Wildfires seldom burn an area with this frequency; it is more probable that 40 to 50 years will elapse between successive large fires over the same area—some areas have not burned for 70 years or more. Because of the shorter time between burns, the average annual burned area can be substantially greater under a full rotational burning program than without. Thus, rotational burning will not necessarily reduce the amount of area burned; it may just replace a few large fires with numerous smaller ones.

Loss of buildings and other improvements directly from prescribed fire is unlikely. Flood and erosion damage, impairment of water quality, air pollution from smoke, and similar undesirable fire effects will occur from prescribed burning, however, just as from wildfire. Esthetically, rotational burning is not likely to be much of an improvement over wildfires—a few large fire scars will be replaced with many smaller ones. In time, the accumulated adverse effects of rotational burns may not be smaller—and may even be greater—than those that would occur from wildfires.

High Costs

Unlike timber stands, much of the chaparral in southern California has little readily burnable surface fuel. Most of the fuel is standing, and a large part of it—65 to 85 percent—is living, with high moisture content. The dead fuel is fairly uniformly distributed through the living material. The chaparral fuel beds are also quite porous—a little solid material occupies a large volume of space. For example, in a typical stand

of chamise 6 feet tall, to total standing fuel is equivalent to a solid layer less than one-fourth inch thick. With these characteristics, southern California chaparral does not burn easily in its natural condition unless the burning conditions are well up in the scale of severity—relatively dry fuels and at least moderate wind speeds.

Under such circumstances, fire burns and spreads just as hot and fast outside a planned burn area as inside. Thus, prescribed burning in the natural fuel would require considerable prefire firebreak construction and a sizable control force on hand during the burning to reduce the risk of escape fires to an acceptable minimum. This would be costly, and the costs would recur each time the area is burned. There are also relatively few days during the year when the fuels are dry enough to burn well and burning conditions are such that risk of fire escape is not excessive. Hence rotational burning over an area the size of southern California would require that manpower and equipment be available in quantity.

To increase the amount of fuel consumed and to allow effective burning during periods when vegetation will not normally burn, the chaparral may be treated. Mechanical crushing of part or all of the brush in place is most effective. This reduces the fuel bed porosity and decreases the moisture content of the living material to a point where it will burn well. Herbicides or desiccating agents to increase the amount of dead and dry material may also be used. But these treatments materially increase costs, and also must be repeated each time the area is burned.

Possible Increased Fire Hazard

Whether rotational burning in chaparral will actually reduce the fuel loading and fire hazard for more than a short time is open to question. Wildfires during severe burning conditions remove a large part of the fuel; in the more intense fires nearly all of it is burned. Under the moderate conditions in which prescribed fires must be conducted, the aboveground portions of most of the shrubs will be killed. But of such material, only the portions less than one-half inch in diameter can normally be expected to be consumed by the fire. In the dry southern California climate, little of the dead and standing shrub skeletons will decay before the next prescribed burn. Thus, rotational burning can add to the amount of dead fuel present—the fuel that is so important in determining the flammability of chaparral.

The possible long-range effects of rotational burning on fuel characteristics must also be considered. Fire has long played a role in the species composition

of southern California chaparral. Those species that could not withstand occasional fires were simply eliminated. When lightning was the main source of ignitions, most fires were probably small and burned with low intensity, since lightning is usually associated with poor burning conditions and also tends to occur in the same general areas. Although it is likely that there were some large fires, it is also likely that most of these burned with low or moderate intensity, because the development of the weather and fuel moisture conditions needed for intense fires following an ignition by lightning is a rare event. But with the advent of man-caused fire sources, the fire potential has changed. Man-caused fire ignitions now occur much more frequently than those from lightning, and often occur when intense fires can develop.

The intensive fire protection which has kept the number and frequency of large fires low despite the large number of fire starts, is sometimes cited as the cause of fuel buildup and conflagration fires. There is little evidence, however, that the fuel buildup was less and that the chaparral lands of southern California burned over more frequently under the lightning fire regime than under present conditions. Rather, the low- or moderate-intensity lightning fires appear to have been replaced with high-intensity man-caused fires.

Since man has become the primary fire starting agent, it is quite probable that the species composition of the chaparral has been changing. Species that can survive occasional low- or moderate-intensity fires can be eliminated by repeated high-intensity fires, and such fires now burn most of the area. For example, there is some indication that the hard chaparral in some areas is being replaced by buckwheat and sage, which burn hot and have an extreme rate of fire spread. Long-lived species, such as big-cone spruce, that withstood earlier fires are disappearing.

To be effective, rotational burning must be done at intervals that are shorter than wildfires are likely to burn the same area. Prescribed fires will generally be of lower intensity than conflagrations, but the repeated burning at short intervals can be expected to increase the fire stress on the chaparral and the species composition may move to a more flammable type.

Although rotational burning, in concept, may seem an appropriate step toward alleviation of the conflagration fire problem, the difficulties of putting the method into practice and its potential adverse effects suggest that its widespread use in southern California may be inadvisable. Rotational burning should probably be confined to situations where

other and more permanent fuel modification is not feasible.

Fuel-Breaks Provide Strips of Modified Fuel

During the 1930's, a program was undertaken to break up the extensive areas of chaparral in southern California through a system of firebreaks. Along many of the major ridges all fuel was removed in a band 300 to 500 feet wide, and lesser firebreaks of the same type were constructed along the spur ridges. The primary purpose of the firebreak system was to provide barriers that would stop the spread of fire without the necessity of using fire crews in hazardous situations or in areas of difficult access. This attempt at conflagration control had disadvantages, however. The firebreaks were expensive to construct and maintain even with the relatively low cost manpower supplied by the Civilian Conservation Corps and similar programs. The swaths cut through the chaparral were unsightly, and erosion from the bared soil was a major problem. Perhaps most important, the unmanned firebreaks failed to stop the spread of fire in the conditions under which conflagrations occur. With the termination of the emergency labor programs, the firebreak concept was largely abandoned.

When the difficult fire season of 1955 again emphasized the problem of extensive areas of chaparral without adequate access, the general concept of pre-constructed firebreaks was revived; but with important differences. Now, instead of leaving the treated areas completely devoid of vegetation as was done in firebreak construction, the tall and dense chaparral is removed and replaced with vegetation that burns less intensely—usually grass. Only a narrow strip near the middle of the modified band of fuel is kept free of vegetation to serve as an access way and a place where backfiring or burning out can be started. The edges of the band are usually made irregular and a few shrubs may be left within the band to give a more natural appearance. These modified bands or "fuel-breaks" vary in width, but are usually 100 to 400 feet wide and are strategically located for fighting fires. Their chief value comes from the rapidity with which a fire barrier can be made in the light fuel, either by removal of the vegetation with manpower and equipment, or more often by burning the fuel in advance of the wildfire.

Fuel-breaks are intended to be manned for use in fire control. But like the firebreaks that preceded them, they are not effective in stopping the head of a hot, fast-running fire in a strong wind. As the band of modified fuel is relatively narrow, the hazard at the head of the fire is still great; often precluding man-

ning of the fuel-break at all. And the spotting problems, along with the difficulty of safely burning out even light fuel in adverse wind conditions, frequently makes fuel-breaks an ineffective barrier to fire in extreme conditions.

A considerable number of miles of fuel-breaks have been constructed. But because of their limitations in fire control, and also because they are generally widely spaced, fuel-breaks have not had a great impact in reducing the burned area or damage caused by conflagration fires. Fuel modification of this type can be effective for less than severe conditions, however, and on some parts of conflagration fires. And a more intensive fuel-break system than presently exists could broaden their usefulness. But fuel-breaks alone are not a complete answer to conflagration fires.

Fuel-Type Mosaics Can Lower Energy Output

The basic philosophy of both fuel-break construction and rotational burning—the replacement of dense chaparral with low energy fuels—holds promise for solution of the conflagration fire problem. In practice, however, each method has limitations. The best approach to conflagration control through fuel modification appears to be the creation of a mosaic of fuel types rather than the mosaic of chaparral age classes envisioned in rotational burning. Extensive areas of chaparral can be broken up by areas of low-energy fuels, thereby providing the fuel situation in which fire suppression techniques are now effective in conflagration conditions. Native chaparral will still be present, but will tend to appear in “islands” rather than uninterrupted stands.

The primary purpose of wildland fire control is the minimization or prevention of fire damage; if fires did not do damage there would be no need to suppress them. Because it is unrealistic to expect that all fires can be prevented, some fire damage is bound to occur even with the best of fire control and any reasonable type and amount of fuel modification. The fuel-type mosaic is designed to assure the control of a fire before it can do an unacceptable amount of damage. The amount of fuel modification needed, then, is partly determined by the direct and indirect fire damage potential in any given area. For high-value watersheds, the acceptable fire size may be less than 100 acres, while in areas of low fire damage potential, burns of several thousand acres may not represent intolerable damage.

Fire behavior also determines the amount and kind of fuel modification required, and this is controlled by the weather, the fuels, and the topography. Topography varies widely over southern California,

and local weather also varies greatly from place to place even under severe conditions. Natural fuel patterns are controlled largely by the soils and climate and these are also variable—some areas cannot support the kind and amount of vegetation that creates a conflagration hazard. In some areas little or no fuel modification will be needed, in others the conventional fuel-break will be adequate, and in still others the fuel modification must be extensive to keep the fire damage within acceptable limits. The amount and kind of fuel modification, then, must be determined by a broad survey of southern California.

Fuel-Type Mosaics Can Be Created in Many Ways

The opportunities and methods for developing fuel-type mosaics are numerous. Where soils and climate permit, chaparral can be replaced with grass as it often is on fuel-breaks. Low-volume and slow-burning plants adaptable to harsh sites are being sought out and developed through research and can be used to replace native vegetation—some plantings have already been made. Use of waste water to irrigate selected plant species to create “green belts” of hard-to-burn vegetation has been demonstrated to be feasible. Thinning of native vegetation to develop recreation areas, such as campgrounds and picnic areas, when combined with modification of fuel on adjacent areas can provide zones where fire can be readily stopped. Golf courses and land planted to useful crops make excellent fire barriers, and encouragement through zoning, tax policies, or subsidies of the use of private land in selected areas for these purposes will aid in the development of fuel-type mosaics.

Many communities in southern California now have ordinances requiring the clearing of dense vegetation from around structures. Along with these ordinances have come intensive education and information programs for homeowners in landscaping techniques to lessen the fire hazard to their homes, and in self-help measures that can be used to help protect their property from wildfire. When applied, all these have been effective in reducing fire losses. Most fire control agencies would like to see existing ordinances strengthened and expanded to include provision for adequate water supplies and access roads for firefighting in housing developments in wildlands, and also to include requirements for fire-resistant building material and construction. There is also growing interest in revamping zoning regulations to prevent building at all in areas where protection of structures from fire would be extremely hazardous and difficult, if not impossible.

Although fuel reduction around individual struc-

tures can be effective in reducing fire losses, this action does little to reduce fire size, since the modified fuel areas are seldom continuous enough to provide an adequate fire barrier. But the fuel reduction measures could be expanded community-wide, extended into adjacent wildlands, and combined with adequate access roads, water supplies, and fire-resistant buildings. Then areas so modified would be relatively safe from wildland fire, and would also provide a barrier to the spread of conflagrations. In effect, housing developments in wildlands could become an asset to conflagration control instead of a liability.

In southern California, compared with other parts of the State, relatively little effort has been made to convert chaparral to grass, particularly on public lands. Mainly this is because suitable areas for conversion are generally too small and grass production too low to make their use attractive for grazing—the economic benefits gained from grazing use alone do not offset the conversion and maintenance costs and the costs of handling livestock in small and scattered areas. But for grass areas to be most effective in conflagration control, the volume of grass must be kept low. An effective way to do this is through livestock grazing. Thus, a land management policy for public lands allowing for free or subsidized use of converted chaparral lands could be justifiable in the interest of fire control.

Few chaparral shrubs are palatable to livestock or game; hence fuel reduction or modification through livestock use is not generally workable. Many of the saltbrush species, however, including natives, are highly palatable and nutritious—some have a nutritional value comparable to alfalfa. Because of their high mineral content, the living material in most saltbrushes burns slowly, and they are well adapted to harsh sites. They develop considerable dead material with age, however, and can become nearly as flammable as chaparral when mature. But managed livestock use of chaparral lands converted to saltbrush can keep both the amount of dead material and total fuel loading low. Hence, free or subsidized use of such lands can result in an effective and durable conflagration barrier.

Similarly, low-cost leasing or subsidized use of public lands for agriculture, or for recreational development by private interests, where the area affected can be of sufficient extent, would encourage the chaparral modification needed for conflagration control.

Fuel-Type Mosaics Are Not a Quick Cure

In an area the size of southern California, development of fuel-type mosaics cannot be accomplished in

a short time. Means of financing must be found, and enabling legislation and policies may have to be formulated to permit effective development of some types of mosaics. And public acceptance of such widespread changes in the wildlands must be obtained.

First, costs of fuel-type mosaics are likely to be high. But besides quick control of fires during severe conditions and substantial reduction of fire damage, important side benefits can accrue. Recreation opportunities should be increased, wildlife habitat improved, more forage produced, and in some areas water yield increased. When properly planned, fuel-type mosaics can also result in a more pleasing landscape than extensive areas of a uniform vegetative type.

Because fire damage is the major consideration in fire control, first priority in the development of fuel-type mosaics should be given to areas where fire damage is likely to be great. When these are reasonably secure, the mosaics can then be expanded to areas of lesser damage potential. It is possible that in some areas adequate fuel-type mosaics cannot be created because of extremely steep terrain and poor soils. In these, rotational burning may be judiciously used.

Complete and Coordinated Planning Is Essential

In essence, the envisioned fuel modification will replace the present wildland vegetation patterns with planned and managed ones. To achieve this, complete and coordinated plans must be developed. As fire does not recognize administrative boundaries, such planning will involve not only fire control agencies, but also local governments, land use planning commissions, and sometimes private interests. Social, economic, land use, and environmental impacts must be determined and evaluated, and the best combinations of fuel modification to achieve adequate fuel-type mosaics for a given area established. Inputs into these plans will be needed from fire control and fire behavior experts, meteorologists, land-use planning specialists, economists, landscape architects, plant ecologists, biologists, recreation planners, and wildland research groups.

Much of the technology needed to create fuel-type mosaics is now available, is being developed, or is susceptible to development through research. Many of the techniques by which type conversion can be done have been demonstrated to be feasible. What is needed now is a comprehensive action plan that will effectively bring this technology to bear on the one factor controlling fire behavior that can successfully be managed and manipulated—the fuel.

To some, the extensive "monkeying with nature" required to replace the present wildland vegetation patterns with planned and managed ones may seem abhorrent. But the impact of man and man-caused fires has already had a massive effect on the natural vegetation, so much so that it is difficult if not impossible to specify what a "natural" vegetative pattern in

southern California really is. And this impact will continue as long as conflagrations are a part of the environment. The only alternative to planned and managed vegetation patterns in southern California appears to be acceptance of the great economic damage, threat to human life, and the unpleasant esthetic and environmental effects of unmanageable wildfire.

The Author _____

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SOME WOODS OF HAWAII..

properties and uses of 16 commercial species

Roger G. Skolmen



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1974. **Some woods of Hawaii . . . properties and uses of 16 commercial species.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 30 p., illus. (USDA Forest Serv. Gen. Tech. Rep. PSW-8)

Information is given for 16 Hawaii-grown species, both native and introduced, of present or potential commercial importance. Descriptive notes include tree characteristics, history, size, and growth rates; the timber volume available in Hawaii; and accessibility for logging. Wood properties, including appearance, weight, shrinkage, strength, workability, seasoning, durability, and finishing, are explained with reference to well-known woods, and present and potential uses are described. An appendix includes technical data. Each species is illustrated in color.

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Over the past several years, much information on the properties and uses of a number of Hawaii-grown woods has been gathered. Most of the data on physical and mechanical properties have been published in various reports by the U.S. Forest Products Laboratory. Several of these reports are now out of print or in short supply, and some available information has not yet been published. This material has been drawn together here and combined with information drawn from the world literature and with some new data gathered for this report.

Each species is covered from many points of view that might be of interest to a wide audience. Comments on the tree, its history, size, and growth rate, the timber volume available in Hawaii, and the accessibility of the timber for logging are given for the benefit of loggers, foresters, history buffs, and tree lovers. Properties of each species are explained in the text by means of general comparison to well-known woods.¹ To satisfy the needs of architects and engineers technical tables are included in the Appendix. Present and potential uses of the woods are described.

Hawaii has about 1 million acres of land with the soils and climate required to produce timber as a crop. This land is primarily in native forest in which the principal species is ohia (*Metrosideros collina*). Koa (*Acacia koa*) is another widespread native species. There are some 30,000 acres in timber plantations of introduced species, and these constitute the bulk of the present timber resource. Altogether, more than 800 tree species grow in Hawaii; only 16 of those presently or potentially important commercially are described here.

Despite its rather heavily forested condition, Hawaii has only a small primary forest products industry. The annual cut of the three sawmills presently operating is less than 3 million board feet, of which well over half is koa. During the 1960's, the Hawaii Division of Forestry made a start toward providing an improved timber resource for the future by clearing about 8,000 acres of low-yield forest and planting fast-growing introduced species with desirable wood properties. Within 10 years, this timber will begin to reach harvestable size. If this program can be continued at an adequate level, a timber processing industry can become important in Hawaii's economy.

In the descriptions of the wood species, all tree and log volume figures are based on the International 1/4-inch rule. Trees specified as sawtimber are those more than 11 inches in diameter breast height (d.b.h.). Logs, unless otherwise specified, are 16-foot lengths of the main stem. Hardwood lumber grades mentioned are those of the National Hardwood Lumber Association.

The specific gravity figures reported were calculated from the volume of the wood at 12 percent moisture content (air dry) and its weight when oven-dry. The density (pounds per cubic foot) figures were calculated for both volume and weight at 12 percent moisture content.

Wood characteristics naturally vary from one piece to another. The descriptions and numerical data in this report apply to the wood as it is usually observed. The information on durability—that is, resistance to decay and termite damage—and the need for preservative treatment applies only to wood use in Hawaii unless otherwise stated. Subterranean and drywood termites are more injurious pests in Hawaii than in most areas in the mainland United States. Decay is also severe in the more humid parts of the islands because of the year-round warm temperatures. Durability is usually described in standard terms: very resistant, resistant, moderately resistant, or non-resistant.

For those interested in a brief evaluation of the 16 wood species described in this report, the following broad observations are offered:

Most plentiful: ohia, robusta, koa

Most attractive in figure or grain: koa, mango, monkey-pod

Most dense: ohia, bluegum, brushbox

Least dense: Molucca albizzia, redwood, Australian toon

Most stable: Monkey-pod, redwood, mango

Strongest in mechanical properties: ohia, bluegum, brushbox

Most easily workable: redwood, Norfolk-Island-pine, sugi

Least susceptible to degrade in seasoning: redwood, sugi, monkey-pod

Most useful for . . .:

flooring: ohia, blackbutt, brushbox

cabinet work: koa, mango, tropical ash

wood turning and carving: monkey-pod, koa, milo

pallets and crating: robusta, saligna, bluegum

wood chips and fiber products: bluegum, saligna.

¹These woods are referred to by their common names; the scientific name is given at the first mention of each species.

KOA

Acacia koa Gray

Trees and Forests

Koa is Hawaii's finest native timber tree. Unfortunately, it grows best in areas that can be converted into good grazing land, and most of the best koa forests have been cleared to develop pasture. Consequently, not much koa is left. Koa seedlings are also palatable to grazing animals, so that the number of young, vigorous koa trees is small.

Koa sawtimber trees are typically 24 inches or larger in diameter and usually contain two 16-foot logs. They have fluted, often crooked main stems which break up into massive, widely spreading branches. Because the trees are old and decadent, butt and crotch rots are common (Burgan, *et al.* n/d). Deep fluting produces bark pockets which are the main cause of degrade in koa lumber.

The remaining koa forest that may be considered commercial is all on the island of Hawaii, primarily in rather inaccessible areas above 4,000 feet elevation on the slopes of Mauna Loa, Mauna Kea, and Hualalai. Timber volume in trees exceeding 11 inches d.b.h. is about 120 million board feet, (Nelson and Wheeler 1963), but less than a third of this is economically harvestable.

Wood Characteristics

Appearance—Koa has pale brown sapwood that changes abruptly into brown to reddish brown heartwood. Sapwood thickness is usually about 1 inch in old butt logs, but may be 2 inches or more in logs from young trees or branches. Heartwood varies in color from tree to tree, ranging from pale blond to deep chocolate brown. Reddish brown is the most common color.

The wood is usually figured by light and dark banding in the growth rings, sometimes prominently so. Grain is slightly to strongly interlocked and wavy. An attractive curly or fiddleback figure is often present. Fairly large vessel elements give the wood a moderately coarse texture.

Weight—Koa has a density of 38 pounds per cubic foot (specific gravity 0.55) when air dry (Gerry 1955; Harrar 1941, 1942²). This density is identical to that of black walnut (*Juglans nigra*), with which wood koa

compares quite closely in most technical properties (Skolmen 1968c).

Shrinkage and stability—The wood has a slight edge on walnut in shrinkage owing to greater uniformity of shrinkage in the radial and tangential directions (Harrar 1942). Once dried, koa remains stable and moves in place only slightly with changes in relative humidity.

Strength—Koa compares closely to black walnut in all its mechanical properties (Skolmen 1968). Like walnut, it has strength more than adequate for table and chair legs² (Gerry 1955). Like walnut, it has hardness not great enough for flooring, but more than adequate for scratch-resistant furniture (Harrar 1942).

Workability—Sharp saws, knives, and sandpaper are essential in machining koa because it is quickly burned by any dull rubbing action. The wood is somewhat harder to saw than its density would indicate, but does not have a pronounced dulling effect on tools. Straight-grained koa machines easily, but figured wood is difficult to shape or plane without tearouts because of irregular grain. Owing to its irregular grain, koa is best surfaced one side at a time with careful attention to grain direction. Lumber should be dried to 12 percent moisture content or less before planing to avoid grain lifting and fuzzy surfaces.

Seasoning—Koa is easily seasoned with little degrade. Some surface checking usually occurs in large cants when they are stored outdoors awaiting manufacture into carvings or veneer, but lumber of normal thicknesses gives no problem so long as good drying procedures are followed.

Durability—The wood is nonresistant to decay (Skolmen 1968a) and is highly susceptible to attack by both *Coptotermes formosanus*, the subterranean termite, and *Cryptotermes brevis*, the drywood termite. In normal use as a furniture and cabinet wood, koa is not subjected to decay or subterranean termite hazards, but in Hawaii it is open to attack by drywood termites. Permanent installations of koa woodwork and paneling should therefore be treated with a termite-repellent chemical.

Finishing—Koa takes a high polish and almost any type of natural finish. It will yellow quickly in the presence of bright sunlight even though well varnished, so is not well suited for exterior trim.

Wood Uses

Koa is primarily a furniture and cabinet wood. About 500,000 board feet are used each year in local furniture manufacture. Many homes and business establishments have some paneling, decorative wood

²Gerhards, C. C. *A limited evaluation of a few strength properties for Acacia koa, Metrosideros collina, and Eucalyptus robusta grown in Hawaii.* 1963. (Unpublished report on file at U.S. Forest Prod. Lab., Madison, Wis.)

work, and furniture of koa since it is the traditional Hawaiian cabinet wood.

The wood is also extensively used for carved bowls and turnery. Articles of koa generally command a premium in price over similar articles made of the more commonly used monkey-pod (*Pithecellobium saman*). Because of its nearly equal radial and tangential shrinkage in drying, koa can be worked into bowls while green and subsequently dried with only slight degrade.

Koa is a good wood for specialty gunstocks (Crane Creek Gun Stock Co. 1962). Selected gunstock blanks have been shipped to two manufacturers on the U.S. mainland for a number of years.

Koa is shipped to several mainland States as well as to Japan as cants and as logs for slicing and peeling into veneer. A local plywood company has also peeled koa for decorative paneling.

Because it is a valuable, scarce commodity with established market outlets, koa lumber is selected and graded to fit the requirements of particular uses. It is not uncommon for veneer manufacturers to visit Hawaii to select the logs and cants they want. Generally, the most colorful and highly figured koa goes into craftwork (carvings and turnery) and gunstocks. Veneer manufacturers use less highly figured but still colorful wood to avoid jointing problems. Low-grade lumber is used for upholstered furniture frames, pallets, and irrigation stakes.

Koa is an attractive, highly useful wood that commands a high price. It could probably fill a much greater and continuing market need if sustained supplies could be developed. Pressures for preservation of native forests—especially on public lands—and lack of programs to regenerate the resource on private lands make future supplies questionable.

MOLUCCA ALBIZZIA

Albizia falcata Fosberg syn. *A. falcata*
(L.) Back. (*A. moluccana* Miq.)

Trees and Forests

Molucca albizzia is the most common of several albizzias growing in Hawaii. Introduced to Hawaii by J. F. Rock in 1917 (Rock 1920), it has been planted on all the islands, both as an ornamental and as a forest tree. The largest plantings are on Kauai and contain 5.1 million board feet of sawtimber (Honda, *et al.* 1967). Until recently, there were about 1 million board feet on the island of Hawaii, but most of this has been cut (Nelson and Honda 1966). Other plantings of significance are on Lanai (525,000 board

feet) and Oahu (367,000 board feet) (Wong, *et al.* 1967; Nelson, *et al.* 1968). The timber on Kauai is generally accessible to logging, but there is no industry there to use it.

Albizzia trees, when forest grown, usually produce a single stem that is generally erect but contains several crooks. The trees grow extremely fast on favorable sites (annual rainfall of 60 to 150 inches, less than 2,500 feet elevation), and can produce 48-foot merchantable stems, 27-inches in diameter, in as little as 13 years. Most of the available timber is in stands 40 to 45 years old, and typical trees in these stands are 24 inches in diameter with three 16-foot logs.

Wood Characteristics

Appearance—Sapwood is wide and white, and is not always distinguished from heartwood. Heartwood is pale yellowish-brown with a pinkish tinge. The grain is usually straight and shallowly interlocked. The wood is coarse in texture, with little or no figure. When green, it has a strong odor, somewhat like garlic, which disappears in dry wood.

Weight—Albizzia is a light wood—weighing 23 pounds per cubic foot (specific gravity 0.33) when air dry (Gerhards 1966a). This weight is comparable to that of black cottonwood (*Populus trichocarpa*) and Engelmann spruce (*Picea engelmannii*).

Shrinkage and stability—Shrinkage of the wood is small, and compares with that of Engelmann spruce and ponderosa pine (*Pinus ponderosa*) (Gerhards 1966a). In service, movement with humidity changes is also small.

Strength—Albizzia is generally comparable to ponderosa pine in strength properties (Gerhards 1966a). It is slightly stronger when green, but weaker when air dry. It is a little stronger than average for a wood of its density.

Workability—Logs usually contain some growth stress, which causes slight end-splitting and slight spring in sawing. Butt logs frequently contain a core of brittleheart, 4 to 6 inches in diameter, about the pith. Tension wood, which causes fuzzy surfaces after planing, is also common in the species.

Albizzia saws well, but has a slight dulling effect because of stress-caused saw-pinching. Dust from sawing or other machining operations of both green and air dry wood, is irritating to mucous membranes.

The machining properties of the wood have been evaluated at the Forest Products Laboratory (Peters and Lutz 1966). It planes nearly as well as red alder (*Alnus rubra*), behaving best with a cutting angle of 10°. It shapes well, but tension wood, when present,

produces fuzzy end grain and both fuzzy grain and chipping on side grain. It is about equivalent to basswood (*Tilia americana*) in turning. It proved to be good in boring and mortising. Sharp tools are required to cut this soft wood cleanly.

Albizzia has been used for veneer in Hawaii and was excellent for this application. It can be rotary-cut cold and produces smooth veneer, as long as knives are sharp. It glues well. Abnormally large chucks are required to hold this soft wood and to extend beyond the brittleheart core; this results in larger cores than normal. End splits caused by growth stress are troublesome in peeling and often cause splitouts on the lathe.

Seasoning—Lumber stains rapidly if left close piled and should be quickly piled for drying after being sawn. It is an easy wood to season, drying rapidly with little degrade.

Durability—Albizzia is not resistant to decay or insects and should not be used in exposed situations unless treated with preservatives (Osborne 1970). It is relatively easy to treat.

Wood Uses

About 1 million board feet of albizzia timber has been cut in Hawaii. Most of this volume has been used for core stock veneer. The wood is excellent for this purpose, producing a high yield of low-density, clear veneer.

The lumber produced has had a variety of end uses, but the bulk of it has gone into light-weight pallets, crating, and shelving. One company in Hilo made several ladders of the wood and has used them successfully for several years.

The wood should be suitable for some internal furniture parts. It is well suited for use as filler, or core stock.

Albizzia should be a good species for board, paper, and other fiber products. Large volumes of light-colored, easily chippable wood can be grown rapidly.

"NORFOLK-ISLAND-PINE"

Araucaria columnaris (Forst.) Hook.

Trees and Forests

Although some true Norfolk-Island-pines (*Araucaria heterophylla*) grow in Hawaii, most of the trees called by this name are believed to be Cook- or columnar-pine (*A. columnaris*), which they closely resemble. In this report, the probably incorrect but familiar common name is used.

"Norfolk-Island-pine" was introduced to Hawaii about 1860 and has been planted on all the islands, both as an ornamental and as a forest plantation tree. It is now being grown extensively for Christmas trees, which are marketed both locally and on the mainland. Most sawtimber stands are on Maui and Oahu at elevations below 2,000 feet and are generally readily accessible to logging. Many of these stands are too highly valued for recreation or scenic beauty, however, to allow logging.

The standing volume of sawtimber is 2.8 million board feet on Maui, 2 million on Oahu, and 1.5 million on Kauai (Wong, *et al.* 1969; Nelson, *et al.* 1968; Honda, *et al.* 1967). Most of the timber on the island of Hawaii has already been cut. The stands are predominantly 40 to 50 years old and contain trees typically about 18 inches d.b.h. and 90 feet tall. In these stands, the butt log is usually free of branches, but dead branches are retained on the second and third logs. The tree produces a whorl of branches about every foot up the trunk, so the wood is knotty. Little clear wood is produced except in the lower half of the butt log in old trees. Trees are easily logged because the branches usually break off cleanly when a tree hits the ground.

Wood Characteristics

Appearance—"Norfolk-Island-pine" has a pale blond, lustrous heartwood that is not differentiated from the sapwood. Frequent and evenly spaced knots in the wood are dark reddish brown to black. Most trees contain some compression wood, which produces lumber streaked with bands of pinkish-hued or darker brown wood. Occasional trees contain some heartwood streaked with dark brown discolorations. Growth rings can usually be discerned on end-grain surfaces, but rarely are distinct on radial or tangential faces. The wood is bland in figure and fine in texture. Strongly spiraled grain has been observed in some trees, and may be common in the species.

Weight—The air-dry weight of the wood is 31 pounds per cubic foot (specific gravity 0.44), placing the wood in the moderately heavy classification along with Douglas-fir (*Pseudotsuga menziesii*) (Gerhards 1967).

Shrinkage and stability—Shrinkage in drying is small, and the wood moves only slightly with changes in relative humidity (Gerhards 1967). It shrinks somewhat less than Douglas-fir and a little more than western redcedar (*Thuja plicata*).

Strength—"Norfolk-Island-pine" is comparable in most strength properties to Douglas-fir of the "inland," or Intermediate type described in the U.S.

Department of Agriculture Wood Handbook of 1955 (Gerhards 1967). It is higher in shearing strength and hardness than Douglas-fir, but not quite as strong or stiff in bending. It is suitable for most general construction purposes so long as lumber containing severe diagonal grain (greater than 1 inch in 1 foot) is eliminated and so long as the weakening effect of its numerous knots is considered.

Workability—Clear wood saws and machines well in all operations, but clear wood is seldom encountered. The dense knots and irregular grain around knots cause some chipping and tearouts in planing dry lumber, but no particular difficulty is encountered in planing green lumber or in rotary peeling of green logs.

Seasoning—Blue stain develops rapidly in logs and also lumber if left close piled, so rapid conversion and drying is necessary. Compression wood that occurs in the trees has so far caused no problems of warping or excessive longitudinal shrinkage in lumber or plywood manufacture. Knots usually check minutely when the wood is dried and also bulge slightly when the surrounding wood shrinks—in lumber that has been planed while green, and in veneer.

Durability—“Norfolk-Island-pine” is highly susceptible to decay and insect damage and should not be used in exposed situations in Hawaii unless treated with preservatives. Because of its susceptibility to termites, it is desirable to treat the wood for any use where some permanence is desired. The wood is permeable to preservatives and easily treated (Skolmen 1971a).

Wood Uses

About 1 million board feet of “Norfolk-Island-pine” timber has so far been cut in Hawaii. About 150,000 feet of this volume was converted into veneer and plywood, the rest into lumber.

Most of the lumber has been used for residential framing and sheathing, the lowest grades going into pallets. Some “knotty pine”-type paneling has been produced and used quite effectively. “Norfolk-Island-pine” has an especially attractive luster, but for best appearance adjacent boards must be staggered lengthwise to avoid even rows of knots across a wall.

The wood is also used to a limited extent in the craft industry. Branch nodes are cut from trees of suitable size and turned into bowls and bracelets so that the knots form decorations around the piece.

The wood should be well suited for paper and fiber products. Its fiber tracheids are among the longest of any softwood, and the wood is essentially colorless.

BLUEGUM

Eucalyptus globulus Labill.

Trees and Forests

Bluegum was introduced to Hawaii about 1880 and has been planted on all the islands. Easy to propagate and adapted to many sites, it was planted widely for fuelwood and to satisfy certain Territorial leasing requirements before 1920. Below about 2,500 feet, it is usually poorly formed and spiral grained. At higher elevations it is well formed and spiral grain is much less common. In one 60-year-old stand on the island of Hawaii, a volume of 108,000 board-feet per acre was measured on a sample plot. And one tree in this plot contained 12 logs, each 16 feet long.³ Bluegum is naturalized in Hawaii. It invades pasture lands both by root sprouting and through seeding.

Most of the bluegum is on Hawaii and Maui. Hawaii has 56 million board feet of sawtimber, almost all on land leased or owned by Kukaiau Ranch on the northeast slope of Mauna Kea.³ Maui has an estimated 100 million board feet, a large portion of which is committed to a sawmill on the island.³

Bluegum was classed as a noncommercial species in forest resource inventories because it often has excessive and troublesome shrinkage in drying and excessive spiral grain. Apparently, this limitation is not universal, and the State has sold bluegum stumpage to private industry.

Wood Characteristics

Appearance—Bluegum has grayish-white sapwood about 1 inch thick which changes abruptly, but not too distinctly, into a pale yellow-brown heartwood similar in color to oak. It usually has interlocked grain, the degree of interlocking varying in localized areas. Localized areas of spiral and wavy grain may occur in otherwise straight-grained wood. The wood is moderately coarse in texture and has a faint figure imparted by light and darker banding in the growth rings.

The wood frequently contains gum veins, which are shakelike separations in the growth rings filled with a dark-reddish resinous material. These veins are a serious degrading feature.

Weight—Bluegum grown in Hawaii weighs 55 pounds per cubic foot (specific gravity 0.79) when air dry. It is a very heavy wood—generally comparable to

³ Unpublished records on file at Hawaii Division of Forestry, Honolulu.

true hickories, such as shagbark hickory (*Carya ovata*) and to ohia (*Metrosideros collina*).

Shrinkage and stability—Bluegum has a large shrinkage in drying, shrinking 8 percent radially and 12 percent tangentially in drying from green to oven-dry. It is unstable and changes dimensions appreciably with small changes in relative humidity.

Strength—The mechanical properties of Hawaii-grown bluegum have not been measured. Mechanical properties given for wood grown in Australia are for somewhat denser wood than that grown in Hawaii (Bolza and Kloot 1963). On the basis of wood density, the mechanical properties of Hawaii-grown bluegum are assumed to be comparable to those given for blackbutt (*E. pilularis*) and ohia. The wood is probably very strong in bending, very stiff, fairly high in shock resistance (if brittleheart and severe spiral grain are excluded), and very hard.

Workability—Bluegum trees contain little growth stress. End splitting and spring are much less troublesome than in other eucalypts, such as robusta and saligna. Brittleheart is common in the central core of logs, but is less extensive than in robusta or saligna eucalyptus. For a dense wood, it saws well. Spring is not a serious problem in making accurate cuts. Logs can be sawed for grade without excessive turning. Tearouts are common in planing in localized areas of severely interlocked or irregular grain. The wood rotary-peels well when heated.

Seasoning—Bluegum is a somewhat difficult wood to season. It is prone to checking on flat-sawn faces, and to deep end-checking, but if properly piled, it does not warp or collapse excessively. Quartersawn stock will season well, but should be sawed ¼-inch oversize per inch in thickness to overcome the large shrinkage. A small amount of 4/4-inch, flat-sawn stock has been successfully seasoned by slow air-drying in the humid Hilo area to equilibrium at 20 percent moisture content followed by mild kiln-drying. In much harsher air-drying conditions on Maui, straight, flat lumber is also being produced. It is possible to recover about one-third of the volume loss caused by shrinkage by steaming lumber when it has reached about 20 percent moisture content. Steaming (or reconditioning) is a normal practice used in Australia with this and other difficult species. In rotary-cut veneer manufacture, if 48-inch sheets are desired, green veneer should be clipped to at least 54-inch widths to allow for the large shrinkage in drying. Buckling in drying is a serious problem with bluegum veneer, but can be partially overcome by using screen-type driers.

Durability—The only tests of the durability of

bluegum grown in Hawaii have been tests of fence posts. These tests indicate that the wood is moderately resistant to decay, but quite susceptible to subterranean termite attack—at least when sapwood is present as it was in the posts (Skolmen 1971). The wood is not suitable for use in exposed situations unless pressure treated with preservatives. No tests of pressure treating Hawaii-grown bluegum heartwood have been made, but the wood will probably be difficult to impregnate. Heartwood should be suitable for indoor use without treatment, but sapwood is known to be susceptible to powder-post beetle attack and probably to drywood termites as well.

Wood Uses

A small amount of rotary-cut bluegum veneer has been produced and laid up into sheathing-grade plywood. Except for its very heavy weight as compared with commonly used Douglas-fir plywood, it seems satisfactory.

About 20,000 board feet of bluegum lumber were produced by one sawmill. The bulk of this was used in pallets and was a complete failure. The pallets were made of green wood which collapsed, split at the nails, and warped to a remarkable degree. The rest of the lumber, of a higher grade, was carefully dried and run into flooring, which was satisfactory and was sold. The wood has also been used on a small scale for corral fences and gates, and for fence posts.

At another sawmill, some 150,000 board feet of lumber and timbers have been produced. Some of the lumber was used green as shed siding and in planter boxes and held up remarkably well. The rest was seasoned and for the most part performed satisfactorily. Occasional planks sawn from near the pith had extensive deep surface checking and honeycomb, but most of the lumber produced held its grade in drying. A large shipment of timbers was sent to Alaska for use as dock fenders. The customer is reportedly well satisfied.

Bluegum is suitable for heavy construction and for flooring in areas with stable humidity. It would be a good wood for pulp and fiber products if this type of industry develops in Hawaii.

BLACKBUTT

Eucalyptus pilularis Sm.

Trees and Forests

Blackbutt was introduced to Hawaii about 1910. Small stands are found on all the islands, but the volume of standing sawtimber is negligible except on

Oahu, which has 2.5 million board feet (Nelson, *et al.* 1968). The tree is somewhat difficult to establish in plantations, so has not been favored in forestation work. Most plantations are in drier sites where annual rainfall ranges from 40 to 75 inches.

Blackbutt grows rapidly and on better sites, trees can exceed 20 inches d.b.h. and 160 feet tall in 35 to 40 years. Stems frequently are slightly crooked. Like most other eucalypts, blackbutt self-prunes early and produces a high proportion of clear wood.

Wood Characteristics

Appearance—Blackbutt has a white sapwood which changes abruptly into a pale brown, oak-colored heartwood. Grain is usually straight, but occasional trees produce wood abundantly marked with birdseye mottling. The normal straight-grained wood is unfigured except for slight color differentiation within growth rings. It is a medium-to-fine-textured wood, and though it lacks the broad ray structure of white oak (*Quercus alba*), bears such a close resemblance to oak that it has been used for door jambs in homes floored with that wood.

Weight—Average density of the wood when air dry is 46 pounds per cubic foot (specific gravity 0.66) and much more uniform than in robusta or saligna (Gerhards 1966b). Wood near the pith is usually brittleheart, particularly in butt logs. Such wood is lower in density than normal wood and often contains visible compression failures.

Shrinkage and stability—Blackbutt has a large shrinkage in drying, although somewhat less than robusta or saligna (Gerhards 1966b). It is reasonably similar to white oak and shagbark hickory in shrinkage and instability with relative humidity changes.

Strength—Blackbutt wood is exceptionally stiff and will deflect less under load than any commonly used mainland wood (Gerhards 1966b). It is stiffer in bending and stronger in compression parallel to the grain than robusta or saligna and has about the same shock resistance, hardness, and shear strength as saligna. It is comparable to the heavier hickories, such as shagbark hickory, in all strength properties except shock resistance. It is, however, quite high in shock resistance and approaches white ash (*Fraxinus americana*) in this property so long as the brash central core of brittleheart is excluded.

Workability—Blackbutt saws and machines well, but is more difficult to work than woods of lower density. Occasional pieces with interlocked grain tend to tear out in planing and molding.

Like logs of most other eucalypts in Hawaii, blackbutt logs contain growth stress which causes them to

split on the ends and spring in sawing. Growth stresses do not seem to be as troublesome in this species as they are in saligna and robusta.

The principal degrading factors in blackbutt lumber and veneer are gum veins, which are in about one tree in five.

Seasoning—The wood is subject to collapse in drying and should be air-dried to below 30 percent moisture content before kiln drying. Flat-sawn boards check more in drying than do robusta and saligna, but this has not been a serious problem in drying the wood.

Durability—The wood is moderately resistant to decay and will provide good service in above-ground uses. It is not as resistant to decay as robusta and saligna, but appears to be more resistant to subterranean termites than either one. In a durability test lasting 9 years and 6 months, and including redwood (*Sequoia sempervirens*), western redcedar, and other durable species, blackbutt was the only wood that was not attacked by subterranean termites or other wood-boring insects (Skolmen 1968a). Attack by drywood termites has not been observed in blackbutt, but it is probably susceptible to them as are most other woods. The wood is difficult to impregnate with preservatives.

Wood Uses

Only a few hundred thousand board feet of blackbutt lumber have been produced in Hawaii, as the resource is limited, and little timber is found on the islands with sawmills—Hawaii and Maui.

The lumber that has been produced has been used for flooring, paneling, truck beds, refuse flumes, residential construction, heavy construction, irrigation stakes, and pallets. Thus it has been used for essentially the same products as robusta and saligna.

Blackbutt has been preferred among the local woods for flooring because of its color, resembling oak. The wood has performed well in the few flooring installations made. A few pieces of furniture have also been made of blackbutt on a trial basis and have stood up well in service.

The wood should be somewhat superior to robusta and saligna for pulp because of its light color, which permits easy bleaching.

ROBUSTA

Eucalyptus robusta Sm.

Trees and Forests

Robusta was introduced to Hawaii from Australia about 1885 and has been extensively planted on the

six main islands. It grows well on a wide variety of sites and can be seen in its best form and size in numerous plantings above the sugarcane fields on the Hamakua Coast of the island of Hawaii. As most of the robusta was planted by the Civilian Conservation Corps during the 1930's, the plantations are still quite young.

Robusta trees have thick, soft, deeply furrowed bark somewhat similar to the bark of redwood trees. They usually have a single, straight main stem for about half their total height. At wet sites, trees in open stands often produce aerial roots from major branch crotches. Frequently, small buttresses are also produced.

The bulk of the robusta timber volume is on Hawaii and Maui and on these islands is generally accessible to logging. The volume of standing sawtimber on these two islands amounts to 150 million board feet (International ¼-inch rule) contained in trees 11 inches d.b.h. and larger (Nelson and Honda 1966; Wong, *et al.* 1969). Sawtimber trees are commonly 18 inches in diameter and contain three 16-foot logs. Much of this timber is now assigned by long-term contract to two lumber producers.

The yield of No. 1 Common and better lumber from mill-run logs averaged 44 percent in two studies (Malcolm 1961; Skolmen 1970).

Wood Characteristics

Appearance—Robusta has a pale brown sapwood which changes abruptly into a reddish-brown heartwood. The heartwood is pale red when fresh cut and darkens with continued exposure to light. Generally, wood near the pith is much lighter in color than later produced heartwood. Grain is interlocked, and occasionally produces a ribbon figure on quartersawn faces. Usually, the only figure present is caused by color variation in the heartwood. Texture is fairly coarse.

Weight—Robusta has an average density of 46 pounds per cubic foot (specific gravity 0.66) when air dry (Youngs 1960). Density is quite variable, however (Skolmen 1972a). Wood near the pith may be only 29 to 30 pounds per cubic foot; wood in the outer part of the stem—the wood that produces lumber of high grade—is often 52 or more pounds per cubic foot. As the heavier wood is in the greatest volume, for practical purposes robusta may be compared to the heavier hickories (*Carya* spp.) in density.

Shrinkage and stability—Robusta has a large shrinkage in drying and is subject to considerable dimensional change with changes in atmospheric humidity (Youngs 1960; Skolmen 1963). This con-

dition is usually not a problem in Hawaii, where humidity is uniform the year round at any one location, but it can be troublesome on the mainland.

Strength—Robusta compares quite closely to Philippine apitong (*Dipterocarpus* spp.) in both green and air-dry strength properties (Skolmen 1963). Among mainland hardwoods, it compares fairly closely with white oak. It is stronger than white oak in all properties except shock resistance.

Robusta does not have an air-dry modulus of elasticity sufficiently higher than Douglas-fir to justify modifying the depth dimension of robusta structural members, as has been tried by some manufacturers. From the data for moduli of elasticity of Douglas-fir and robusta, it can be calculated that an air-dry robusta board 15/16-inch thick will deflect over a given span about as much as an air-dry Douglas-fir board 1-inch thick. It should therefore be possible to use 15/16-inch robusta in place of 1-inch Douglas-fir. In lumber manufacturing, however, it is impractical to be concerned with such a small dimensional difference. Shrinkage variation and sawmill inaccuracies negate initial sawing to such a close tolerance.

Centered around the pith of almost every log is a 4- to 6-inch core of brittleheart. Brittleheart is extremely weak in shock resistance, having only 29 percent of the toughness of normal robusta wood (Skolmen and Gerhards 1964). It is therefore unsuitable for most uses and is best discarded. An estimated 18.5 percent of the total volume of robusta sawtimber is brittleheart (Skolmen 1973).

Workability—Robusta saws easily for a dense wood, but gummy water-soluble extractives (kino) in wood build up quickly behind saw gullets when sawing both green and dry wood. This gumming can be reduced in the sawmill by lubricating saws with a water spray. The wood turns and bores well, but tear-outs in planing and molding are frequent unless a low cutting angle (20° is recommended) and slow feed are used (Youngs 1960).

Growth stresses in logs are a serious problem in lumber and veneer manufacture. Log ends usually split badly soon after bucking. Logs and green lumber spring in sawing so that special sawing techniques and equipment are required for the species (Skolmen 1971b). Best results are achieved with a conventional sawmill by (a) sawing short logs, (b) plain sawing, (c) turning after every other cut, and (d) taper sawing to a boxed heart. Splits in log ends are enlarged when logs are heated for peeling or slicing (Skolmen 1967), and also by drying stresses if logs are held for long periods. This problem can be reduced by bucking logs after heating and by storing long logs.

Seasoning—If it is air-dried to below 30 percent moisture content before kiln-drying in carefully constructed lumber piles, robusta lumber can be dried without serious degrade. The most frequent causes of degrade in drying are the extension of pre-existing end splits, stain of sapwood, and ambrosia beetle attack of sapwood (Skolmen 1964). The low-grade central core of light-colored, low-density wood usually collapses in drying, but this wood is seldom used for products where this matters. Small pin knots that are found in almost all robusta lumber invariably check if the wood is dried below about 12 percent, but this has no effect on lumber grade, as knots are defects regardless of checking (Skolmen 1971b).

Durability—Robusta is resistant to decay, in fact, more resistant than western redcedar, but is not equal to redwood in tests made in Hawaii (Skolmen 1968a). It is not recommended for use in contact with the ground, but will give good service in somewhat less hazardous decay situations: boat frames, exterior construction, and picnic tables, for example. Laboratory and field tests have indicated it is slightly less resistant to the subterranean termite than redwood, but much more resistant than are Douglas-fir and western redcedar. Attacks by the drywood termite have been observed in this species, and it does not appear to be resistant to the insect. Robusta heartwood does not accept preservative treatment well. Round posts and poles with sapwood intact can be treated to American Wood Preservers' Association specifications fairly readily, however (Skolmen 1968b).

Finishing—A test of paintability that has been in progress for 7 years is showing that robusta holds conventional oil and water-base house paints better than Douglas-fir, but not as well as redwood and Australian toon (*Toona australis*) (Boone 1966; Skolmen 1972b).

Wood Uses

Robusta is presently the principal species produced by one sawmill in Hawaii. Annual lumber production has varied considerably in the past few years, but is presently at about 1 million board feet.

Most of the lumber produced has been used for pallets. The wood is being used increasingly for house siding, flooring, and paneling. Plywood formerly produced was of construction grades used for concrete forms, sheathing, and floor underlayment.

Robusta has also been used in furniture manufacture, mostly in upholstered frames. A set of 50 chairs made up for an airport restaurant gave excellent service over a 4-year period of hard usage. The

wood is best suited for small-membered designs joined in ways that allow a small shrinkage and expansion with humidity changes. Tests of robusta for case-goods manufacture in Michigan suggested that the wood was too unstable for the extreme humidity changes prevalent there (Skolmen 1971b). In the stable climate of Hawaii, there has been no problem.

Robusta has found use in a variety of other products. It has proved well suited for sawn (not bent) boat frames. It is excellent for stakes used in irrigating sugarcane, and also finds considerable use by the sugar industry for refuse flume construction and conveyor-belt slats. Truck beds and stake sides for trucks are frequently made of robusta, as are corral fences and gates. The wood is also widely used for round and split fence posts.

In addition to the rotary-cut veneer that has been produced, robusta veneer has been sliced on a trial basis by several companies and made up into attractive plywood paneling and door skins. The wood is not ideal for pulp or fiber products because of its dark color and high density, but it may eventually find use in such products, as have other similar hardwoods.

SALIGNA

Eucalyptus saligna Sm.

Trees and Forests

Saligna was introduced to Hawaii in the late 1880's and has been widely planted for watershed protection and timber production, particularly since the early 1960's. Some foresters have questioned the identity of the trees called *Eucalyptus saligna* in Hawaii. Many of the trees are probably hybrids of *E. saligna* and *E. grandis* and some may in fact be *E. grandis*.

Whatever their genotype, the trees grow extremely rapidly on favorable sites, often attaining diameters over 20 inches and heights over 160 feet in only 30 years. Even at 10 years of age, trees are frequently over 10 inches in diameter and 100 feet tall.

Saligna stands are on all the major islands and are generally in areas of easy access. Hawaii and Oahu have the most *saligna*. Hawaii has 14 million board feet of sawtimber, mostly growing along the Hamakua Coast (Nelson and Honda 1966). Oahu has 8 million feet, mainly in the Ewa Forest Reserve (Nelson, *et al.* 1968). Typical trees in 40-year-old stands are 20 inches d.b.h. and contain five 16-foot logs.

Wood Characteristics

Appearance—*Saligna* has a pale brown sapwood

about 1½-inches thick which changes abruptly into a pink to light reddish-brown heartwood. Grain varies from straight to strongly interlocked, the latter type producing a ribbon stripe figure on quartered faces. Otherwise the wood has a subdued or bland figure caused by slight color variation and concentrations of vessel elements in the growth rings. Texture is medium. The wood is generally paler in color and finer in texture than robusta.

Weight—Average density, air dry, is 46 pounds per cubic foot (specific gravity 0.66). But fast-grown wood near the pith has a much lower density than that of wood near the bark, which formed later (Gerhards 1965). Higher grades of lumber, being from the outer wood in a log, have a density of about 50 pounds per cubic foot when air dry. So, for most uses, the wood may be compared to shagbark hickory in density.

Shrinkage and stability—Saligna has a large shrinkage in drying and is subject to considerable movement in place with changes in relative humidity (Gerhards 1965).

Strength—Saligna is slightly stronger than robusta in most strength properties, probably because its grain is usually straighter (Gerhards 1965). It is superior to white oak in most properties and exceeds any commonly used mainland hardwood in stiffness.

Most logs contain a core 4 to 6 inches in diameter of brash wood, brittleheart, centered around the pith. Brittleheart is unsuitable for most uses, owing to its extreme weakness in shock resistance. Such wood can usually be recognized by its lower density, "fuzzy" sawn end-grain surfaces, and lighter color than sound heartwood.

Workability—Saligna saws and machines normally for a wood of its density. Wood with interlocked grain is subject to tearouts in planing and molding unless a low cutting angle (20°) and slow feed are used. Because of its straighter grain, the wood machines a little better than robusta.

Growth stress is a serious problem in logs. Logs split open on the ends soon after bucking, often quite deeply. Lumber and cants bow (spring) as they come off the saw, and logs spring on the carriage (Skolmen 1967). Stresses should be equalized by frequent turning of the log in sawing on a conventional carriage. Stress problems are generally more severe in saligna than in robusta. Suggested sawing procedures for stressed logs are covered in the discussion of robusta.

Seasoning—Saligna can be kiln dried without serious degrade if it is first air-dried to below 30 percent moisture content. Because of its large shrinkage in drying, it requires careful attention in drying to avoid

warp, checking, collapse, and honeycombing. Low density wood will usually collapse in drying, but such wood is normally otherwise unmarketable so the problem is a minor one. If desired, the collapse and a considerable portion of total shrinkage can be recovered by steaming the wood for several hours when it is at about 20 percent moisture content.

Durability—The wood is resistant to decay, but not nearly so resistant as redwood. It is not recommended for use in contact with the ground. Its resistance to termites has not been specifically tested, but stake tests in the ground indicate that saligna is roughly as resistant to subterranean termites as robusta (Skolmen 1968a). This similarity would rank it superior to Douglas-fir and western redcedar, but less resistant than redwood. Attacks by drywood termites have not been observed in saligna, but it is probably susceptible to them. Saligna is difficult to impregnate with preservatives.

Wood Uses

Saligna has not been extensively cut or marketed in Hawaii as yet. The saligna that has been produced has been largely mixed with robusta and sold as pallet lumber and flooring. It is suitable for the same products as robusta and except for its paler color, resembles it quite closely.

Saligna is an important timber species in South Africa and Brazil. In South Africa, it is used for general construction, mine props, poles, furniture, and a multitude of other products, including paper, rayon, and hardboard. In Brazil, it is the mainstay of the steel industry, which, lacking coal, uses saligna charcoal for fuel. It is also manufactured into paper, hardboard, and particle board in Brazil. Saligna has good potential for such uses in Hawaii as well, because it grows so rapidly on a variety of sites.

TROPICAL ASH

Fraxinus uhdei (Wenzig) Lingelsheim

Trees and Forests

In the late 1800's, two trees of this Mexican species were planted on Oahu—one in Nuuanu Valley and one in Kalihi Valley. These two trees were the primary seed source for almost all the tropical ash planted in Hawaii. The Division of Forestry discovered about 1920 that the tree was easy to propagate in the nursery and hardy in field planting. It was therefore used for many small plantings in forest reserves on all the main islands.

In 1960, the Division of Forestry began planting

the tree on a large scale in the Waiakea Forest Reserve near Hilo. These plantings were specifically aimed at timber production. This more extensive use of the tree continued for about 4 years, but was then greatly diminished in favor of other species. Tropical ash is not now being used in the tree planting program because it tends to produce poor form in plantations. If the tree form can be improved through research, its use may be resumed. Planting spacing studies indicate that improvement is possible.

Hawaii is the only island with a significant volume of sawtimber at present. The volume amounts to 1.3 million board feet in trees that are typically 18 inches d.b.h. and contain two 16-foot logs. Most of this timber is along the Maulua Trail at 4,500 feet elevation on the land of Laupahoehoe. The rest, about 400,000 feet, is mostly in scattered stands in the vicinity of Honokaa (Nelson and Honda 1966).

Merchantable tropical ash trees usually have small buttresses and a slightly fluted stem. Because of the early growth habit of the tree, the butt log, if branch free, is usually clear of knots to the pith. It saws out a high yield of high-grade lumber. Tiny bud knots are fairly common in otherwise clear wood, but are considered by local users to be an enhancement, rather than a defect. The trees usually contain growth stresses, which cause immediate splitting of log ends.

Wood Characteristics

Appearance—Tropical ash wood is blond without differentiation between sapwood and heartwood. It is a ring-porous wood, and is moderately fine in texture and straight grained. The growth rings and parenchyma tissue give it an attractive figure similar to that of white ash (*F. americana*), but more subdued.

Weight—It weighs 35 pounds per cubic foot (specific gravity 0.50) when air dry, so is similar in density to black ash (*F. nigra*) (Youngs 1960). Density is fairly uniform throughout a cross section.

Shrinkage and stability—Shrinkage is appreciably less than most mainland ash species and is generally comparable to black cherry (*Prunus serotina*) (Youngs 1960). It is quite stable in place, moving little with changes in relative humidity.

Strength—Tropical ash is similar to black ash in most strength properties. It does not have the exceptional strength and toughness for which white ash is noted, but has adequate strength and hardness for use in furniture and cabinet work. It is not, however, suitable for high quality handle stock as wide-ringed white ash of similar appearance would be (Youngs 1960).

Workability—The wood is easy to saw. Logs and

cants spring in the sawmill, but not to the extent that eucalypts do. Tropical ash machines well. It planes, shapes, turns, bores and mortises with little tearout, chip marking, fuzziness, or other problems.

Seasoning—Tropical ash seasons easily and with little degrade. End splits caused by growth stress extend in drying; this extension is the main cause of drying degrade. The wood is quite susceptible, however, to stain and insect damage, both in the log and immediately after conversion, and thus requires quick handling from the forest to the drying yard. It is desirable to dip-treat lumber directly off the mill to reduce later damage by ambrosia and powder-post beetles in the drying yard.

Durability—The wood is nonresistant to decay and insect attack. For any use in Hawaii where insect damage is a major problem, it should be treated with preservatives. It is easily pressure-treated and can generally be treated through and through with light-oil-borne preservatives.

Wood Uses

It is unfortunate that so little tropical ash is available in Hawaii because it is readily accepted in the market. It is primarily a furniture and cabinet wood and has been used for both furniture parts and finish furniture. It has also been used for paneling and molding.

Rotary-cut and sliced veneers have been produced on an experimental basis and made up into panels. The wood lacks sufficient figure to be outstanding as a face veneer, but with its high yield of defect-free material should be excellent for crossbanding.

In general, tropical ash may be considered a useful medium-density hardwood suitable for a wide range of applications—in the nature of yellow poplar (*Liriodendron tulipifera*) of the East Coast and red alder of the West Coast.

SILK-OAK

Grevillea robusta Sm.

Trees and Forests

Silk-oak was introduced about 1880 from Australia and planted on all the main Hawaiian Islands in both wet and dry sites. It has become naturalized widely and reproduction is often girdled or poisoned on ranches where it is considered a noxious weed (Nelson 1960).

The tree almost always produces a straight, erect stem—even when open grown. It grows well in plantations, achieving excellent growth on good soils with

60 to 80 inches of annual rainfall. It will also grow in areas with rainfall as low as 30 inches, but much more slowly.

Most of the silk-oak sawtimber resources are on Hawaii and Oahu. Hawaii has 3 million board feet, mainly in Kau and North Kona (Nelson and Honda 1966). Oahu has 2.5 million feet, mostly in the Honouliuli Forest Reserve (Nelson, *et al.* 1968). The stands are generally accessible for logging, but it is doubtful that much logging will be done on Oahu, where the trees are needed for watershed cover and scenic amenities. Merchantable trees are typically 16 to 18 inches d.b.h. and contain three 16-foot logs. Occasional trees contain numerous shake-like gum veins, but in general, lumber grade yield from logs is high.

Wood Characteristics

Appearance—Silk-oak has a cream-colored sapwood about 1 inch thick, which changes abruptly into a pale pinkish-brown heartwood. The heartwood becomes yellow brown on aging, losing its pink cast. The wood has large, prominent rays which give a pronounced ray fleck on quarter-sawn faces. While Australia's supplies lasted, silk-oak, along with the plane tree (*Platanus acerifolia*), was the "lacewood" of world trade, owing to this attractive figure (Boas 1947). "Lacewood" is now supplied by *Cardwellia sublimis*, another Australian species with similar wood. In addition to the prominent ray figure, dark and light color banding in the growth rings provides figure on plain and quarter-sawn faces. The wood resembles sycamore (*Platanus* spp.) in figure, but is yellower. Grain is usually somewhat undulating, but not interlocked. Texture is medium.

Weight—Silk-oak weighs 40 pounds per cubic foot (specific gravity 0.57) when air dry, similar to paper birch (*Betula papyrifera*) (Youngs 1964). It is somewhat lighter than American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), and sugar maple (*Acer saccharum*), and heavier than black cherry and sweet-gum (*Liquidambar styraciflua*).

Shrinkage and stability—Shrinkage in drying is relatively small and compares with that of black cherry, silver maple (*Acer saccharinum*), and red lauan (*Shorea negrosensis*) of the Philippines (Youngs 1964). Movement in place with relative humidity changes is also relatively small, but as this wood shrinks almost three times as much in the tangential direction as in the radial, it stays in place best if quartersawn.

Strength—The only mechanical property of Hawaii-grown silk-oak that has been measured is hard-

ness (Youngs 1964). Silk-oak has a side hardness when air dry that is similar to that of black cherry and paper birch. Its hardness is more than sufficient for mar-resistant furniture and paneling, but not for flooring.

Strength properties of silk-oak of similar density have been measured in Australia and South Africa. The wood from Australia had a breaking strength comparable to pecan hickory (*Carya illinoensis*) and some of the true oaks (Bolza and Kloot 1963); the wood grown in South Africa was weaker, more like silver maple (Scott 1953). The Hawaii-grown wood was harder than wood from either of these sources.

Workability—Silk-oak saws and machines with ease. It planes, shapes, bores, and mortises nicely and is one of the best woods in all-around machinability ever tested by the U.S. Forest Products Laboratory.⁴ Ray tissue tends to lift with small moisture changes and the wood usually requires sanding immediately before finishing to obtain a smooth surface.

This wood has caused serious dermatitis in a number of people who have worked with it (Youngs 1964). Susceptibility varies, but appears to be most common in fair-skinned Caucasians. Green wood is more allergenic than dry wood, but sawdust of both green and dry wood has caused rashes. Silk-oak shavings and sawdust spread in a University of Wisconsin dairy caused a rash on cow udders. Furniture and other articles made of dry, finished wood are apparently safe to handle as no incidents have been reported.

Seasoning—The wood seasons well in 1-inch-thick boards (Skolmen and Smith 1962). Thicker stock requires slow air-drying followed by a mild kiln schedule to avoid honeycombing. Sapwood is highly susceptible to ambrosia beetle and powder-post beetle attack; rapid conversion and preservative dipping of green lumber are recommended. Tiny pin knots are common and would be a serious degrading factor if classed as defects (Malcolm 1961).

Durability—Silk-oak is moderately resistant to decay and termites (Skolmen 1968a). It is not suitable for use in exposed situations unless treated with preservatives. Attack by drywood termites has been observed in this wood. The wood is readily treated with preservatives, can be readily stained, and finishes well. It tends to yellow with prolonged exposure to light.

Wood Uses

The supply of silk-oak lumber has been sporadic.

⁴Unpublished report on file at U.S. Forest Products Lab., Madison, Wis. 1961.



Koa



Molucca albizzia



Bluegum eucalyptus



Norfolk-Island-pine



Robusta eucalyptus



Blackbutt eucalyptus



Saligna eucalyptus



Tropical ash



Silk-oak



Monkey-pod



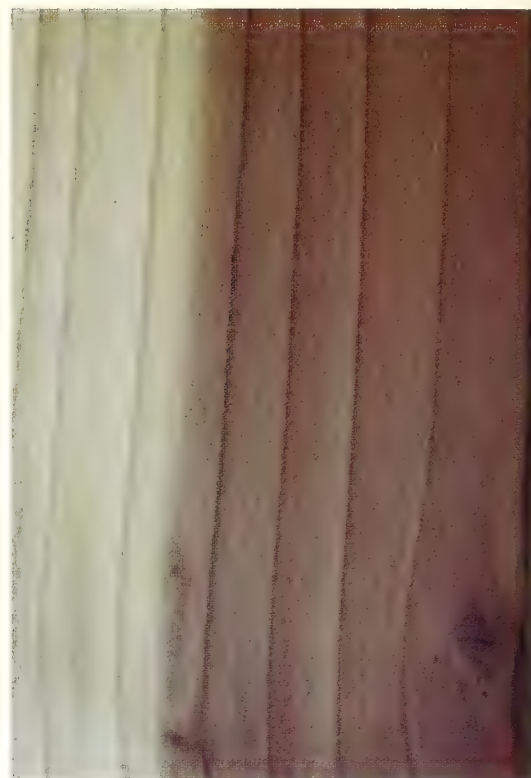
Mango



Ohia



Milo



Redwood



Australian toon



Brushbox

Because of the limited resource, it has not been possible to offer the continuing supply required to develop a broad use pattern. In all, about 500,000 board feet of timber have been cut since the late 1950's.

The wood has been used for the exposed parts of furniture, upholstery frames, drawer sides and backs, turnery, paneling, bin pallets, standard pallets, and many other items. A house on the island of Hawaii was built entirely with silk-oak framing, flooring, and siding in 1967.

A small furniture company some years ago made several sets of natural-finish bedroom furniture from silk-oak, but despite advertising pointing out the unique wood, consumer acceptance was disappointing. The wood was apparently too similar in appearance to natural-finish oak, which had been out of style for many years.

Other furniture companies have since used the wood successfully for stained or painted furniture parts, interior parts, and upholstery frames. These companies would continue to use the wood if supply could be assured.

Because of its relatively light weight, the wood was found acceptable for pallets used in handling air cargo, and a considerable volume has been used for this purpose.

Silk-oak is, of course, a well-known face veneer species under the name of lacewood, and is well suited for this use. It is readily peeled and produces excellent core stock and crossbanding when rotary cut. Face veneer is always sliced on the quarter to obtain the lacelike ray-fleck figure. So far, however, use of Hawaii-grown silk-oak as veneer has been only on an experimental scale.

For a hardwood, the wood has long fibers—average 1.75 mm. This, coupled with the pale color of the wood and its moderate density, should make silk-oak well suited for pulp and fiber products.

MANGO

Mangifera indica L.

Trees and Forests

Mango was introduced to Hawaii sometime before 1825 from at least three different countries—Chile, the Philippines, and China—and was taken to all the islands as a desirable fruit tree (Hamilton and Yee 1962). Though now naturalized, it is a large-seeded plant and spreads very slowly. One of the easiest methods of finding old dwelling sites in Hawaii is to locate huge old mango trees. Usually near the trees will be the stonework of old foundations and walls.

These trees are the so-called common mango and are variable in both tree form and fruit type. Other, better flavored fruiting varieties were introduced in more recent times, the most important of these introductions being the Pirie in 1899 and the Haden in 1930.

Mango trees in the forest generally occur singly or in small groups, usually in drainage bottoms. Access to the trees is quite variable, but usually difficult. Some of the oldest trees reach diameters of 8 to 10 feet and heights of 80 to 100 feet. The trees usually have a short, deeply fluted main stem and massive branches. Occasionally, the trees have a surprisingly good form with a straight cylindrical stem containing one or two 16-foot logs. There are estimated to be about 4 million board feet of mango sawtimber in the State.

Wood Characteristics

Appearance—Mango is a lustrous, blond wood without distinct sapwood. Old trees sometimes contain a small central core of dark brown or gray streaked wood, which is probably the true heartwood. Mango wood is moderately coarse in texture, often with irregular, strongly interlocked grain. Wood that reaches the market place is usually stained, particularly in the vessel elements. This staining is easily prevented during processing, but is generally preferred by customers. In typical stained wood, the pores (vessels) are black and the surrounding wood is marbled with blue-gray, green, yellow, and sometimes pink discoloration.

The wood is commonly figured by grain irregularities. Figuring may take the form of mottling, dimples, swirls, ripples, or a pronounced fiddleback.

Weight—Mango grown in Hawaii weighs 40 pounds per cubic foot (specific gravity 0.57) when air dry. This is the same as mango grown in Puerto Rico (Longwood 1961) and within the range of mango grown in India (Ghosh 1963). It is thus a little heavier than black walnut, and a little lighter than white ash (U.S. Forest Products Laboratory 1955).

Shrinkage and stability—Mango has a small lateral shrinkage in drying and remains stable in service where relative humidity changes are large (Crane Creek Gun Stock Co. 1962). Longitudinal shrinkage of highly figured wood sometimes exceeds 0.5 percent, which is quite large compared to most woods, but this has not caused any seasoning problems in Hawaii.

Strength—Wood of specific gravity similar to Hawaii-grown wood has been tested in India (Ghosh 1963) and was found to be similar to black ash and

black cherry in bending strength, stiffness, and crushing strength, but more on the order of butternut (*Juglans cinerea*) or silver maple in shock resistance. Its hardness is similar to that of black walnut—it can be just barely dented with a fingernail.

These properties indicate that the wood should serve well if used for finish furniture of moderately small-membered design. The wood does not have a sufficiently high shock resistance for use in extremely thin-membered designs.

Workability—Mango saws easily, but its machining properties vary with grain irregularities. Grain tear-outs are common in wavy-grained wood when planed, turned, or shaped. The wood bores and mortises well, however (Longwood 1961). It shows scratches from sanding unless a fine grit is used for final finish.

Highly figured wood has been tried as a sliced face veneer. Such wood is highly fragile as veneer due to its intensely wavy grain. It is easily broken in handling and chipped in jointing. It glues well, however.⁵

Seasoning—Mango seasons easily—thick lumber can be kiln-dried from the green state by a fairly harsh schedule without degrade. In the wet climate of Hilo, where most mango lumber has been produced, the wood will invariably stain if set out for normal air-drying. Stain can be avoided by immediate kiln drying of freshly sawed lumber. Mango is also highly susceptible to stain and insect attack when in log form and requires rapid processing.

Durability—The wood is not resistant to decay and is highly susceptible to insect damage in Hawaii even when used indoors as furniture. The wood should be pressure-treated with preservatives for any use—indoors or out. Excellent penetration and retention of preservatives are easily achieved.

Wood Uses

Mango has been used in Hawaii on a small scale for craftwood products, furniture, paneling, and gunstocks. As a craftwood, it is used primarily for turned plates and bowls, though some carved bowls have been made of the wood. For this purpose highly figured wood is used and varicolored, stained wood is preferred. Furniture has consisted of chairs, occasional tables, and cabinets, which have all been quite attractive and have given good service. Paneling used in one home and in a church has likewise been highly successful.

Mango is of an unusual color for gunstocks, but has performed well in this use. It is a much more

stable wood than walnut, the standard wood for stocks, so holds sight alignment better. It is more difficult to finish, especially in checkering of the grips, but the beauty of the mango stock is said to be worth the extra effort required (Crane Creek Gun Stock Co. 1962).

Besides having these special ornamental uses, mango is a good general utility hardwood suitable for pallets, crates, and upholstery framing.

OHIA

Metrosideros collina (Forst.) Gray
subspecies *polymorpha* (Gaud.) Rock.

Trees and Forests

Ohia, a native species, is the most abundant tree in Hawaii, but commercially operable stands occur only on the island of Hawaii. The island has about 360 million board feet in trees over 11 inches d.b.h. (Nelson and Wheeler 1963). Trees in the better stands are commonly 18 to 24 inches in diameter and contain two 16-foot logs. Low per-acre yields are common. The better stands yield from 5,000 to 6,000 board feet per acre. Roads into the ohia rain forest are few; therefore the timber is relatively inaccessible to logging.

The stems are commonly deeply fluted and often contain over-grown tree stems of other species and treefern trunks. Despite these defects, yield of No. 1 Common and better lumber usually exceeds 50 percent of log volume for logs over 16 inches in diameter. Severe spiral grain is often present in logs. Although this condition does not affect standard hardwood grades, it results in diagonal grain that weakens the wood for construction purposes.

Wood Characteristics

Appearance—Ohia has a pale brown sapwood that grades gradually into a reddish to purplish-brown heartwood. Occasional trees contain heartwood with a color similar to black walnut. Grain is usually interlocked, and together with color banding in the growth rings, gives the wood an attractive subdued figure. Texture is medium.

Weight—Ohia weighs 57 pounds per cubic foot (specific gravity 0.81) when air dry (Youngs 1960). It is heavier than any wood commonly used in the United States.

Shrinkage and stability—Shrinkage in drying is large and movement in place with humidity changes is also large (Youngs 1960). In Hawaii, where the climate is very uniform throughout the year, ohia stays

⁵Unpublished results of tests at U.S. Forest Products Laboratory, Madison, Wis.

in place well. In other areas with large variations in relative humidity, shrinking and swelling of ohia might cause problems.

Strength—Ohia is generally comparable to shagbark hickory in its strength properties, though it is substantially weaker in toughness, impact bending strength, and strength in compression perpendicular to the grain (Youngs 1960). It exceeds white oak in almost all strength properties. A very hard wood, it exceeds sugar maple in this property.

Workability—Ohia was previously reported to have a pronounced dulling effect on tools (Youngs 1960). This effect has not shown up in more extensive work with the wood. It saws and machines with difficulty, but no more so than would be expected for a wood of its density.

Inserted saw teeth and tooth holders designed for sawing frozen hardwood perform well with ohia, as also do carbide tipped sawteeth. The wood is better than many commonly used mainland woods in shaping and boring, but poorer in planing and turning. A cutting angle of 20° works best in planing (Youngs 1960).

Seasoning—Because of its large shrinkage and interlocked grain, ohia is prone to warping during seasoning unless carefully piled. Sticker spacing should be no more than 2 feet. The wood is not prone to surface checking. Ohia should be air-dried to a moisture content below 30 percent before kiln-drying.

Durability—Ohia is nonresistant or moderately resistant to decay and is not recommended for use in contact with the ground unless treated with preservatives (Skolmen 1968a). It is less resistant than Douglas-fir to decay. It has shown considerable resistance to the subterranean termite in laboratory tests. Though not immune to attack by this insect, it was much less severely attacked than redwood or western redcedar. The wood does not seem to be preferred by the drywood termite, but damage by this insect is common in old installations of ohia. Ohia is somewhat variable in its acceptance of preservatives, but in all commercial pressure-treating done with the wood, penetration and retention of both oil- and water-borne preservatives have met or exceeded American Wood Preservers Association standards.

Wood Uses

Ohia is an excellent wood for strip flooring and this is its main use in Hawaii. Its next most common use is for ship blocking in the drydocks at Pearl Harbor. Another important use of the wood has been for stakes used to brace water barriers in irrigation ditches in sugarcane culture. It has been used fairly

extensively as wharf fenders and other marine construction, both pressure-treated and untreated. It is also used in pallets and conveyor belt slats. In general, it is well suited to any use requiring great strength, hardness, and abrasion resistance in which its heavy weight is not a disadvantage. For example, ohia has proved excellent for pile-driver cushions—circular blocks of wood placed between the hammer and concrete piles to prevent shattering.

Ohia has been sliced and rotary-peeled into veneer. It makes up into attractive plywood paneling, but is not preferred as a veneer species due to its tendency to buckle in drying. With a screen-type drier designed to hold the veneer flat, excellent veneer can be produced from the wood.

Ohia is also used in Hawaii for decorative poles in residential construction and business establishments. With bark removed and given a clear finish the poles have an attractive rustic appearance. Poles used are generally in the 5 to 8 inch diameter range and 8 to 10 feet long.

Hardboard has been produced experimentally from ohia groundwood and found to meet Federal specifications (Swartz 1960). Medium-density particleboard has also been produced experimentally from ohia. Though the wood is not ideal for fiber products because it has short fibers, high density, and dark color, it should be usable for some pulping processes and products.

MONKEY-POD

Pithecellobium saman (Jacq.) Benth.;
syn. *Samanea saman* (Jacq.) Merr.

Trees and Forests

Monkey-pod seed was brought to Hawaii from Mexico in 1847 (Anon. 1938). One seedling raised was planted at Koloa, Kauai, and another on the site now occupied by the Alexander Young Building in Honolulu. The tree was early recognized as a desirable shade tree and was soon planted on all the islands. It is primarily a roadside and garden tree, but is also found near old home sites along streams out in the forest. It has become naturalized in several pasture areas and is spreading. A few forest plantations have also been made with monkey-pod.

The tree usually has a short main stem which breaks up into massive, wide spreading branches. When forest-grown, the stem will sometimes be limb-free for 24 feet or more, but such growth is rare. Typical older monkey-pod trees are over 30 inches d.b.h. and have an 8- to 12-foot butt log. The

branches contain a large volume of wood and are usually used as well as the main stem.

It is difficult to estimate accurately the volume of monkey-pod present in the islands because of the sparse, irregular occurrence of the tree, its use as a yard and street tree, and the difficulty of estimating branch-wood volume. Garden trees and roadside trees are cut as urbanization intensifies. These cuttings form the main source of monkey-pod wood processed in Hawaii. At least 6 million board feet of monkey-pod sawtimber are present in Hawaii. The heaviest concentrations are on the island of Hawaii, in a belt along the Kona coast, in Kau, and in Waipio Valley; and on the west side of Kaneohe Bay on Oahu. Logs are generally sold to mills by tree-trimming companies that are paid to remove unwanted or dangerously decadent trees from yards and roadways. The resource is not plentiful.

Though Hawaii is famous for carved monkey-pod bowls, the tree is found in the tropics all over the world. Originally from northern South America, primarily Venezuela, it goes by many names in the countries to which it has been introduced. In most English-speaking countries it is called raintree, while in the Philippines it is called acacia. Today, most of the wood seen in carved bowls, even in Hawaii, is wood that was grown in the Philippines and Indonesia. As in Hawaii, yard and street trees are the principal source of logs in the Philippines, and this resource is becoming increasingly scarce.

Wood Characteristics

Appearance—Monkey-pod has a cream-colored sapwood 1 to 2 inches thick that changes abruptly into a golden-brown to dark-brown heartwood. The wood is coarse textured and usually prominently figured with light and dark bands of color in the growth rings and by varying degrees of interlocking in the grain. Occasionally, the wood is marked with wavy or rippled figure and ribbon striping is common in quarter-sawn faces. Color and figure vary from tree to tree.

Weight—Monkey-pod grown in Hawaii weighs 36 pounds per cubic foot (specific gravity 0.52) when air dry. This is a little heavier than monkey-pod grown in Venezuela (Wangaard, Koehler, and Muschler 1954) or Puerto Rico (Longwood 1961) and probably results from the tendency in Hawaii to use wood from branches as well as from the main stem. Branch wood is generally of higher density than wood in the stem. The wood is comparable in density to sweetgum and black cherry.

Shrinkage and stability—Monkey-pod has a very low shrinkage in drying and is stable once dried. This

low shrinkage gives monkey-pod its high rank as a craftwood species. It can be worked into shape while green and dried afterwards. With most woods, such a practice would result in badly misshapen and checked articles, but with monkey-pod there is hardly any spoilage from degrade resulting from drying.

Strength—The mechanical properties of Hawaii-grown monkey-pod have not been tested, but properties of the same wood grown in Venezuela and of similar specific gravity indicate what can be expected of it (Wangaard, Koehler, and Muschler 1954). It compares with sweetgum and bigleaf maple (*Acer macrophylla*) in hardness and with silver maple in bending strength and stiffness. The wood is strong and hard enough to use in furniture.

Workability—Monkey-pod saws easily and well, but is not as good in other types of machining as its uses would indicate. Machining tests of wood grown in Puerto Rico, which was considerably lower in density than Hawaii-grown wood, indicated that its irregular grain frequently resulted in torn grain and fuzziness in machining (Longwood 1961). This problem has not been observed as a serious one in Hawaii, but small tearouts in planing are not uncommon. When dry, the wood is poor in turning, but when green it turns and carves exceptionally well. It sands and takes finishes well.

Seasoning—Monkey-pod wood seasons easily. Owing to its low and uniform shrinkage it dries with very little degrade from checks, splits, or warp. When bowls that have been turned or carved while green are dried, about 10 percent are reduced in value owing to effects of drying, usually minute end checks. This proportion of loss is remarkably low for wood handled so harshly. Free-form tabletops sawn to shape from green wood occasionally split at the ends in drying, but the problem is not considered serious by manufacturers.

Durability—The wood is resistant to decay and insects. This, of course, applies only to heartwood. In its usual indoor uses about the only hazard to which monkey-pod is exposed in Hawaii is the drywood termite. Tests of the wood in Puerto Rico indicate that it is resistant to this insect (Wolcott 1946).

Wood Uses

The use of monkey-pod for decorative carved and turned articles probably originated in Hawaii. This use of the wood began on a commercial scale about 1946 and became so important an industry that 10 years later Hawaii was importing large quantities of the wood from other islands in the Pacific. Today, high labor costs in Hawaii and intense competition

from Southeast Asia have greatly reduced the size of the local craftwood industry, but it is still important. To compete, the local industry is gradually changing its emphasis from monkey-pod to other more uniquely Hawaiian woods, such as koa and milo (*Thespesia populnea*).

The main products made of monkey-pod in Hawaii are craftwood articles (mostly carved bowls), free-form coffee tables, and furniture. At least one company still specializes in coffee tables made of local wood, but for the most part the tables are now simply finished in Hawaii, the wood being imported already cut to size and sanded. Many homes in Hawaii have dining room and living room furniture sets made of monkey-pod, but most of these pieces were made about 15 years ago when the wood was "in style."

The wood has also been used for paneling, cabinetry, boatbuilding, and even flooring. It is too soft for flooring, but has performed well in the other uses. In boats, it has been used as a substitute for teak in trim, butt-blocks in planking, and heavy framing members.

Monkey-pod is an excellent ornamental wood that commands a high price. It will probably have continued wide use if supplies are grown, but few land owners or industry agents are interested in this aspect of resource supply. The industry is now mining a resource that is in short supply.

REDWOOD

Sequoia sempervirens (D. Don) Endl.

Trees and Forests

Redwood plantings have been successful on restricted sites in Hawaii, but slow early growth makes it difficult to establish the tree in plantations. Sites where it will grow well are quite limited. But the tree grows on the island of Maui in fairly substantial volume, and on Kauai and Hawaii in lesser volume.

Maui has 280 acres of planted redwood containing 6.2 million board feet of sawtimber—all in the Kula Forest Reserve (Wong, *et al.* 1969). The trees there grow rapidly and with a form generally comparable to second-growth redwood in coastal California. Most of this timber is 35 to 45 years old and still retains dead branches right to the ground, so only low grade lumber would be obtainable from the trees. The Maui redwood is not now easily accessible. Kauai has 230,000 board feet of sawtimber (Honda, *et al.* 1967) and Hawaii has 94,000 (Nelson and Honda 1966). The trees on these islands are not as well formed as those on Maui.

Typical sawtimber trees on Maui are 25 inches d.b.h. and contain four 16-foot logs. Many of the

largest trees (36 to 40 inches d.b.h.) have fungus fruiting bodies on the butt log, suggesting that butt rot might be severe. Early development of deterioration has also been noted in a small stand growing at Honaunau on Hawaii. This condition may indicate that stands grown for timber should be logged while relatively young.

Wood Characteristics

Appearance—Hawaii-grown redwood is quite similar in appearance to open-grown second-growth redwood from California. It is wide ringed (two to four rings per inch), and has a wide band of cream-colored sapwood that changes abruptly into pale reddish-brown heartwood. The summerwood portion of each growth ring is smaller than in California-grown wood.

Weight—The wood weighs 25 pounds per cubic foot (specific gravity 0.36) when air dry (Youngs 1960). This weight is similar to that of close-grown rather than open-grown second growth of California. The wood is not quite as dense as that of old-growth redwood.

Shrinkage and stability—Shrinkage of the wood is small, and is generally comparable to that of close-grown second growth of California. Longitudinal shrinkage is quite low in the Hawaii-grown wood, but volumetric shrinkage is somewhat higher than in any type of California-grown redwood. This difference suggests that the wood may be somewhat more prone to collapse in drying (Youngs 1960). The wood is stable in service, as is California redwood.

Strength—The wood is more shock resistant than any type of California redwood, and compares closely to old-growth redwood in hardness. It is comparable to close-grown second growth in bending strength, but is not as stiff in bending as this type of redwood. It does, however, exceed open-grown second growth considerably in both bending strength and stiffness (Youngs 1960).

Workability—So little Hawaii-grown redwood has been cut that any special sawing and machining peculiarities it may have, have not yet shown up. The wood seems to be like California second-growth redwood in sawing and machining characteristics.

Seasoning—The wood is somewhat wetter when green than most California redwood and may be slightly more prone to collapse. Therefore, air-drying before kiln-drying is probably advisable.

Durability—Hawaii-grown redwood has a larger proportion of sapwood than California-grown redwood. Sapwood is, of course, not resistant to decay and insect damage. Until more information on durability of Hawaii-grown redwood is available, it should

be assumed to be similar to second-growth Douglas-fir in lack of resistance to decay and termites. The wood should be pressure-treated with preservatives for most uses in Hawaii, but this may be difficult. Exploratory tests at the U.S. Forest Products Laboratory indicated that Hawaii-grown redwood is similar to California redwood in being difficult to treat. Preservative penetration is nonuniform in both sapwood and heartwood (Youngs 1960).

Finishing—Because the trees are generally much smaller than redwood cut in California, most of the lumber that will be produced from them will be flat-sawn, rather than quartersawn. For this reason, the Hawaii material will probably not hold paint as well as California redwood. Flat-sawn California redwood does not have good paint-holding properties either.

Wood Uses

The yield of clear wood from young Hawaii-grown redwood will be extremely low and practically all of the clear boards that are produced will be sapwood. The wood will not have the natural durability for which redwood is noted, either. Therefore Hawaii-grown redwood lumber will not substitute for top-grade redwood lumber imported from California. It will not be suitable for single-wall house siding, sills, plates, and water tanks as is the clear, vertical-grained, imported material.

Rather, Hawaii-grown redwood should be considered a general construction and utility softwood similar in use potential to Douglas-fir of "Standard" grade. It should be well suited for house framing and similar uses.

MILO

Thespesia populnea (L.) Sol.

Trees and Forests

Milo may be native to Hawaii, or the species may have been introduced by the Hawaiians. It is widely, although not plentifully distributed throughout the tropics, occurring most commonly along sheltered seashores. It was formerly widely used as a shade tree in coastal areas of Hawaii and was much more common than it is today. In Florida, where it grows naturally, and in California, where it has been planted, it is known as the portiatree.

Milo is a small tree, rarely reaching a height of more than 30 feet, or a trunk diameter of more than 12 inches. It has a low, spreading crown and a short main stem. Trees large enough to contain one 8-foot

saw log are quite rare, but this is not a particular problem to utilization since the wood is used in small pieces for turnery and carvings. Branches as small as 2 inches in diameter are utilized. The milo resource has not been inventoried, but is probably less than 200,000 board feet for the entire State. Milo is usually sold to carvers by the cord or piece, rather than by log scale. The trees, though not common, are usually in easily accessible areas.

Wood Characteristics

Appearance—Milo from the main stem of a tree has a pale brown sapwood sometimes streaked with red, which changes abruptly into a dark reddish-brown to chocolate-brown heartwood. Heartwood from small branches is usually pale reddish-brown. The wood is moderately fine textured with a subdued growth-ring figure consisting of dark streaks. A faint ribbon-stripe figure due to mildly interlocked grain is also common on quartersawn faces.

Weight—Milo is a heavy wood, weighing 43 pounds per cubic foot (specific gravity 0.61) when air dry. It is somewhat variable in density, and usually a little heavier than other common craftwoods such as monkey-pod, koa, and mango. It is comparable in density to such common mainland woods as yellow birch and some of the red oaks (*Quercus* spp.).

Shrinkage and stability—The wood has a small shrinkage in drying and is stable in conditions of changing humidity. Milo is usually worked into bowls and carvings while green, as is monkey-pod. Degrade during subsequent drying is small owing to the low shrinkage of the wood.

Strength—The mechanical properties of milo grown in Hawaii have not been tested, and except for hardness, are unimportant to its sole use here—in craftwork. Wood of somewhat higher density (48 lb./cu. ft., air dry) grown near Bombay, India had a bending strength and stiffness comparable to white oak and some of the pecan hickories (Chowdhury and Ghosh 1958).

Workability—Milo saws and machines easily and well. It is an easily worked wood and carves well either by hand or machine. It turns well, both green and dry. It is considered the best and most easily worked wood of any commonly used for craftwork in Hawaii.

Seasoning—The wood seasons well. It is not prone to warping or checking and can withstand quite harsh drying treatment.

Durability—Milo is reputed to be quite resistant to decay and to drywood termites, though these characteristics have not been tested. Durability is not a

particularly important concern, since practically all the wood is used in turnings and carvings.

Finishing—It can be finished to a high polish, but contains a natural oil that greatly retards the drying of varnish finishes. Normal oil-base varnishes will eventually dry on milo, but require days rather than hours to lose their tack. Lacquers are not affected.

Wood Uses

About 5,000 board feet of milo are used each year in Hawaii by the craftwood industry. Most of the articles made are quite small because the wood is generally available only in small sizes. The more common items are small carved tikis (idols), sculptured faces, turned and carved bowls, and bracelets. Tree stumps with roots still in place are sometimes used for larger sculptured faces.

The wood is also used occasionally in furniture, when larger pieces can be obtained. It has been used in yachts for block (pulley) cheeks and interior trim and also on occasion for gun stocks.

Strips of milo bark are sometimes used as a substitute for twine, but are inferior for this purpose to the more commonly used bark of the related hau tree (*Hibiscus tiliaceus*).

AUSTRALIAN TOON

Toona australis Harms syn. *T. ciliata* v. *australis* (Roxb.) M. Roem.

Trees and Forests

Australian toon was introduced to Hawaii in 1914 (Judd 1920) and was planted in small, scattered stands on all the islands. In 1961, it was selected as a principal species for plantings for timber production by the Hawaii Division of Forestry in the Waiakea Forest Reserve on Hawaii. This reserve now has about 4,000 acres of young Australian toon.

The tree is in the botanical family *Meliaceae*, which includes *Swietenia*, *Khaya*, *Cedrela*, and other genera noted for their superior wood.

No island has even 100,000 board feet of Australian toon sawtimber at present. Stands on Hawaii hold only about 90,000 board feet (Nelson and Honda 1966). Lanai stands hold the next greatest volume with 40,000 board feet (Wong, *et al.* 1967). Better trees in 40-year-old stands are typically 18 to 20 inches d.b.h. and contain two 16-foot logs. Older trees tend to have buttresses and frequently have upper stems that are badly forked or leaning. What little timber is available is generally accessible to logging.

Wood Characteristics

Appearance—Australian toon has cream-colored sapwood which changes abruptly into pale reddish-brown heartwood. The heartwood is pale when first cut, and darkens with age. The wood is ring porous, each growth ring being defined at its beginning by a multiple row of closely spaced vessel elements. The wood is usually straight-grained and has a faint growth-ring figure. Occasional trees produce wood with slightly interlocked grain that produces a ribbon-stripe figure when quartersawn. The figure and general appearance are similar to that of Honduras mahogany (*Swietenia macrophylla*). Texture is moderately coarse and the wood has a cedarlike odor.

Weight—The wood is light, weighing 28 pounds per cubic foot (specific gravity 0.40) when air dry (Youngs 1960). This density is comparable to that of old-growth redwood and red alder. Like the eucalypts, Australian toon has considerable variation in density between wood near the pith and wood farther out in the stem.

Shrinkage and stability—Shrinkage in drying is much higher than the density value of the wood indicates (Youngs 1960). Australian toon more closely resembles such heavy woods as sugar maple and white oak in shrinkage. Movement in place with humidity changes is correspondingly fairly large.

Strength—Australian toon is similar to red alder in most strength properties (Youngs 1960). It is rather soft for use in finish furniture and is easily marred, but can be used in some applications where softness is not a problem. It should be suitable for paneling and some construction uses, such as single-wall house siding.

Workability—The wood is generally easy to saw and machine. Growth stress causes end-splitting and spring in logs, and brittleheart is sometimes present near the pith. There is slight spring in sawing logs, but it is not as pronounced as in the eucalypts. Normal wood finishes well. Occasional tension wood causes fuzzy surfaces in planing; these are difficult to sand smooth unless held with a size.

Seasoning—The wood seasons fairly well despite its large shrinkage. It has some tendency toward end-splitting and warp, but these problems can be reduced by end-sealing and careful piling.

Durability—Australian toon grown in Hawaii is not resistant to decay and should not be used in exposed conditions (Skolmen 1968a). In limited laboratory tests, the wood showed resistance to subterranean termites, exceeding redwood and almost equaling ohia in this characteristic. It has not been observed under attack by drywood termites, but is probably

susceptible to them. Preservative treatment of the wood has not been tried.

Paintability—A test of paintability has shown that the wood holds conventional oil- and water-base paints better than do Douglas-fir and robusta eucalyptus. After 7 years of exposure, the wood showed paint-holding ability equal to that of redwood, and did not bleed extractives as does redwood (Skolmen 1972b).

Wood Uses

So little timber of this species has been cut in Hawaii that no important use patterns have emerged. It has been used for kitchen cabinets and paneling in one instance and found to be too soft for facing on the cabinets. It is fine for paneling, however. One office desk of Australian toon has been made and is holding up very well after several years of use. Although considerable care is required to avoid denting and scratching the wood, a few other furniture pieces have been made of the wood and performance was completely satisfactory. Two furniture manufacturers have used the wood for interior parts—drawer sides and backs and upholstery frames—and were quite pleased with it. Two workmen in one of these plants developed dermatitis from the sawdust, however. Although this is the only instance on record, irritating properties may become a problem.

Veneer was produced by one firm and used for plywood door skins in a State of Hawaii office building. The manufacturer recommended that the wood not be considered a veneer species.⁶ From the plywood produced it was apparent that the logs had not been of sufficiently high grade to produce defect-free face veneer.

Lower grades of Australian toon lumber have been used successfully for pallets and crating.

All in all, it would appear that the wood grown in Hawaii will be an excellent general utility hardwood owing to its easy workability and termite resistance. It may have special applications in home construction as single-wall house siding and interior paneling. It is an attractive wood that might find some use as a cabinet wood, but its softness limits it for this use.

BRUSHBOX

Tristania conferta R. Br.

Trees and Forests

Brushbox was introduced to Hawaii in the late 1800's, when many eucalypts were also brought in. It

grows well in plantations, though usually at a somewhat slower rate than many of the eucalypts. It has been planted in forests on all the islands and is often used as an ornamental yard or street tree.

The main resource of brushbox is on the islands of Hawaii and Oahu. Hawaii has 1.3 million board feet of sawtimber (Nelson and Honda 1966) and Oahu has 1.1 million (Nelson, *et al.* 1968). Only a small volume is present on the other islands. Most stands are 30 to 40 years old, with typical trees about 16 inches d.b.h., containing three 16-foot logs. Stems are usually straight and in closed stands are free of branches for two or more log lengths. Most commonly, the tree is found interplanted with various eucalypts, particularly *E. saligna*, and has been harvested only as a secondary species in such stands. The brushbox on Hawaii is generally accessible for logging. Stands on Oahu will probably be maintained for watershed protection and scenic beauty with only limited logging for stand improvement.

Wood Characteristics

Appearance—Brushbox has a pale brown sapwood which changes abruptly into a pinkish-brown or greyish-brown heartwood. Texture is medium to fine, and grain is mildly interlocked and sometimes wavy. The wood is usually lacking in prominent figure.

Weight—Brushbox grown in Hawaii weighs 47 pounds per cubic foot (specific gravity 0.67) when air dry. It is similar in weight to white oak, and also to robusta eucalyptus.

Shrinkage and stability—It has a fairly large shrinkage in drying and is unstable in conditions of varying humidity. Its shrinkage is a little less than that of robusta and saligna eucalyptus.

Strength—The mechanical properties of Hawaii-grown brushbox have not been measured. Brushbox grown in Australia is usually more dense (55 lb./cu. ft., air dry) (Bolza and Kloot 1963), and is slightly stronger than robusta in most properties and slightly weaker than ohia. The less dense Hawaii-grown wood should be equivalent in strength properties to robusta, or to white oak. The central portion of butt logs may occasionally be brittleheart.

Workability—As brushbox logs contain little growth stress, they do not end-split badly or spring badly in sawing. Lumber can be sawed without any particular difficulty other than that caused by the somewhat high density of the wood. Brushbox in Australia is reputed to be highly abrasive to saws, but this characteristic has not been noted in Hawaii. The wood planes well, provided a low-knife angle is used to reduce tearouts in the interlocked grain on quar-

⁶Personal correspondence with R. C. Stadelman, Nickey Brothers, Inc., Memphis, Tenn., May 30, 1961.

tered faces. Results in Australia indicate that it does not steam-bend well (Boas 1947).

Seasoning—Brushbox is difficult to season. It tends to warp in drying and will also collapse. If rapidly air-dried, flat-sawn faces check badly, but in the humid climate of Hilo, surface checking is not a problem. The wood can be successfully dried in well-made piles, but should be air-dried to below 30 percent moisture content before kiln-drying.

Durability—Wood grown in Australia is reported to be resistant to decay and termites (Boas 1947). Results with the wood in Hawaii are variable: in one instance a number of small-diameter poles have given excellent service for more than 40 years in an area of extremely high decay and subterranean termite hazard. Near this location, brushbox fence posts of similar size have failed in only a year or two (Skolmen 1971). Hawaii-grown brushbox should be considered moderately resistant to decay and termites until more information is gathered. It is a difficult wood to pressure treat with preservatives.

Wood Uses

The only use so far made of brushbox lumber in Hawaii has been for pallets. In these pallets the wood was used green in mixture with robusta, and was apparently satisfactory.

Brushbox should be suitable for the same uses as other dense hardwoods grown in Hawaii, such as robusta, saligna, and ohia. It should be particularly well suited for use as flooring. Other uses include truck beds, conveyor slats, and irrigation stakes.

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APPENDIX

Table 1—Moisture content, specific gravity, and shrinkage of 16 Hawaii-grown woods

Species				Shrinkage from green to . . .				Sources
				air-dry ²		oven-dry		
	Trees tested	Moisture content	Specific gravity ¹	Radial	Tangen-tial	Radial	Tangen-tial	
	No.	Percent		Percent				
<i>Acacia koa</i>	3	(³)	.53	—	—	5.5	6.2	Gerhards 1963; Harrar 1941-42
Koa	3	12	.55					
<i>Albizia falcataria</i>	5	57	.32	1.6	3.7	3.2	6.2	Gerhards 1966a
Molucca albizzia	5	12	.33					
<i>Araucaria columnaris</i>	5	91	.42	1.5	2.6	3.5	5.3	Gerhards 1967
"Norfolk-Island-pine"	5	12	.44					
<i>Eucalyptus globulus</i>	7	60	.67	5.3	9.1	8.0	12.3	(⁴)
Bluegum	7	12	.79					
<i>Eucalyptus pilularis</i>	5	82	.59	2.8	5.8	5.9	10.0	Gerhards 1966b
Blackbutt	5	12	.66					
<i>Eucalyptus robusta</i>	8	88	.60	2.9	6.7	6.1	10.7	Dohr ⁵ ; Youngs 1960
Robusta	8	12	.66					
<i>Eucalyptus saligna</i>	10	77	.59	3.8	8.8	6.5	12.1	Gerhards 1965
Saligna	10	12	.66					
<i>Fraxinus uhdei</i>	5	46	.47	—	—	3.5	7.4	Youngs 1960
Tropical ash	5	12	.50					
<i>Grevillea robusta</i>	8	110	.51	1.2	4.2	2.7	7.7	Youngs 1964
Silk-oak	8	12	.57					
<i>Mangifera indica</i>	2	72	.55	1.1	2.6	2.9	5.9	(⁴)
Mango	2	12	.57					
<i>Metrosideros collina</i>	11	67	.70	—	—	6.9	12.1	Youngs 1960
Ohia	11	12	.81					
<i>Pithecellobium saman</i>	4	132	.49	.8	1.4	2.3	4.4	(⁴)
Monkey-pod	4	12	.52					
<i>Sequoia sempervirens</i>	5	156	.35	—	—	2.3	5.3	Youngs 1960
Redwood	5	12	.36					
<i>Thespesia populnea</i>	2	74	.58	—	—	—	—	(⁴)
Milo	2	12	.61					
<i>Toona australis</i>	4	109	.35	—	—	4.3	9.8	Youngs 1960
Australian toon	4	12	.40					
<i>Tristania conferta</i>	4	89	.61	2.6	6.1	5.0	9.5	(⁴)
Brushbox	4	12	.67	—	—	—	—	

¹Based on volume at test and oven-dry weight.

²"Air-dry" is about 12 percent moisture content.

³Green.

⁴Data published herein for the first time.

⁵Dohr, A. W. Results of limited tests of *Eucalyptus robusta* from Hawaii. 1959. (Unpublished report on file at U.S. Forest Products Lab., Madison, Wisc.)

Table 2—Moisture content, specific gravity, and static bending properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii

Species and source of wood	Trees tested	Moisture content	Specific ¹ gravity	Stress at proportional limit	Static bending				Sources
					Modulus of . . .		Work to . . .		
					Rupture	Elasticity	Proportional limit	Maximum load	
	No.	Pct.		Psi	Psi	1,000 Psi	In-lb per cu-in	In-lb per cu-in	
<i>Acacia koa</i>	3	(²)	0.53	5,500	9,000	1,520	1.18	12.9	Gerhards 1963;
Koa (Hawaii)	—	12	.46	10,100	13,300	1,570	3.58	9.1	Gerry 1955
<i>Albizia falcataria</i>	5	57	.32	3,400	5,300	1,080	.63	5.5	Gerhards 1966a
Molucca albizzia (Hawaii)	5	12	.33	4,800	8,400	1,280	1.04	8.7	
<i>Araucaria columnaris</i>	5	91	.42	4,100	7,100	1,410	.70	8.1	Gerhards 1967
“Norfolk-Island-pine” (Hawaii)	5	12	.44	6,000	11,000	1,560	1.31	8.8	
<i>Eucalyptus globulus</i> ³	18	(²)	.73	7,590	12,200	2,160	—	—	Bolza and
Bluegum (Australia)	18	12	.87	13,400	21,200	2,950	—	—	Kloot 1963
<i>Eucalyptus pilularis</i>	5	82	.59	7,000	11,700	2,200	1.28	12.5	Gerhards 1966b
Blackbutt (Hawaii)	5	12	.66	10,600	18,000	2,700	2.41	17.3	
<i>Eucalyptus robusta</i>	8	88	.60	6,500	10,400	1,780	1.38	9.2	Youngs 1960
Robusta (Hawaii)	8	12	.66	8,200	15,600	2,200	1.77	14.5	
<i>Eucalyptus saligna</i>	10	77	.59	7,100	11,500	1,980	1.50	12.5	Gerhards 1965
Saligna (Hawaii)	10	12	.66	9,900	16,400	2,390	2.33	17.4	
<i>Fraxinus uhdei</i>	5	46	.47	4,600	8,500	1,410	.87	11.0	Youngs 1960
Tropical ash (Hawaii)	5	12	.50	6,800	12,800	1,660	1.62	12.0	
<i>Grevillea robusta</i>	8	110	.51	—	—	—	—	—	Youngs 1964
Silk-oak (Hawaii)	8	12	.57	—	—	—	—	—	
<i>Mangifera indica</i>	—	(²)	.59	—	8,700	1,300	—	—	Ghosh,
Mango (India)	—	(⁴)	.61	—	12,800	1,600	—	—	et al. 1963
<i>Metrosideros collina</i>	11	67	.70	6,000	10,100	1,800	1.18	10.6	Youngs 1960
Ohia (Hawaii)	11	12	.81	10,700	18,300	2,370	2.75	16.7	
<i>Pithecellobium saman</i>	2	(²)	.48	4,880	8,100	910	1.51	10.4	Wangaard 1954
Monkey-pod (Venezuela)	2	12	.50	6,080	8,860	1,100	1.97	7.8	
<i>Sequoia sempervirens</i>	5	156	.35	3,500	6,100	770	.91	7.5	Youngs 1960
Redwood (Hawaii)	5	12	.36	4,600	8,700	980	1.22	8.3	
<i>Thespesia populnea</i>	—	(²)	.65	—	13,400	1,500	—	—	Chowdhury &
Milo (India)	—	(⁴)	.69	—	17,100	1,700	—	—	Ghosh 1958
<i>Toona australis</i>	4	109	.35	3,400	5,700	1,010	.67	7.2	Youngs 1960
Australian toon (Hawaii)	4	12	.40	6,000	10,600	1,300	1.61	9.5	
<i>Tristania conferta</i>	19	(²)	.69	6,530	11,400	1,700	—	—	Bolza and
Brushbox (Australia)	19	12	.79	10,500	17,600	2,220	—	—	Kloot 1963
<i>Pseudotsuga menziesii</i>	—	38	.45	4,500	7,600	1,570	.75	7.6	USFPL 1955; ⁵
Douglas-fir (W. Coast)	—	12	.48	7,800	12,200	1,950	1.77	9.8	Youngs 1960
<i>Sequoia sempervirens</i>	16	112	.38	4,800	7,500	1,180	1.18	7.4	USFPL 1955;
Redwood (old-growth) (Calif.)	16	12	.40	6,900	10,000	1,340	2.04	6.9	Youngs 1960
<i>Thuja plicata</i>	15	37	.31	3,200	5,100	920	.63	5.0	USFPL 1955
Western red cedar (W. Coast)	15	12	.33	5,300	7,700	1,120	1.44	5.8	
<i>Shorea negrosensis</i>	5	(²)	.46	4,890	7,770	1,440	—	—	Lauricio and
Red lauan (Philippines)	5	12	.49	7,080	11,500	1,700	—	—	Bellosillo 1963
<i>Dipterocarpus grandiflorus</i>	5	(²)	.62	4,780	8,480	1,750	—	—	Lauricio and
Apitong (Philippines)	4	12	.72	10,200	16,700	2,500	—	—	Bellosillo 1963
<i>Quercus alba</i>	20	68	.60	4,700	8,300	1,250	1.08	11.6	USFPL 1955
White oak (Central states)	20	12	.68	8,200	15,200	1,780	2.27	14.8	

¹ Based on oven-dry weight and volume at test.

² Green.

³ Includes *E. bicostata* and *E. St. Johnii*.

⁴ Air-dry.

⁵ USFPL = U.S. Forest Products Laboratory.

Table 3—Hardness, toughness, and compression properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii

Species and source of wood	Trees tested	Compression parallel to grain		Compression perpendicular to grain		Hardness		Toughness		Sources
		Stress at proportional limit	Maximum crushing strength	Psi	Psi	End	Side	Radial	Tangential	
	No.	Psi	Psi	Psi	Psi	Lb	Lb	In-lb	In-lb	
<i>Acacia koa</i> Koa (Hawaii)	3	2,600	3,900	—	—	950	870	—	—	Gerhards 1963; Gerry 1955; Harrar 1941-42
<i>Albizia falcataria</i> Molucca albizzia (Hawaii)	—	—	7,300	1,364	1,780	1,340	1,110	—	—	Gerhards 1966a
<i>Araucaria heterophylla</i> "Norfolk-Island pine" (Hawaii)	5	1,880	2,610	230	800	410	360	250	250	Gerhards 1967
<i>Eucalyptus globulus</i> ¹ Bluegum (Australia)	5	2,420	4,490	400	1,130	580	450	190	180	Bolza and Kloot 1963
<i>Eucalyptus pilularis</i> Blackbutt (Hawaii)	5	2,500	3,170	—	1,010	600	500	170	180	Gerhards 1966b
<i>Eucalyptus robusta</i> Robusta (Hawaii)	5	3,570	5,840	—	1,510	1,030	650	120	130	Youngs 1960
<i>Eucalyptus saligna</i> Saligna (Hawaii)	18	5,000	6,180	760	1,500	1,580	1,650	—	—	Gerhards 1965
<i>Fraxinus uhdei</i> Tropical ash (Hawaii)	18	8,190	12,000	1,410	2,370	2,560	2,580	—	—	Youngs 1960
<i>Grevillea robusta</i> Silk-oak (Hawaii)	5	4,500	5,720	—	1,460	1,120	1,100	350	340	Gerhards 1965
<i>Mangifera indica</i> Mango (India)	5	5,670	9,760	—	2,240	1,530	1,380	390	370	Youngs 1960
<i>Metrosideros collina</i> Ohia (Hawaii)	8	3,560	5,260	—	—	1,100	970	260	260	Gerhards 1966b
<i>Pithecellobium saman</i> Monkey-pod (Venezuela)	8	4,150	8,200	—	—	1,670	1,330	270	280	Youngs 1964
<i>Sequoia sempervirens</i> Redwood (Hawaii)	—	—	—	—	—	—	—	—	—	Ghosh <i>et al.</i> 1963
<i>Thespesia populnea</i> Milo (India)	11	3,090	4,720	640	1,680	1,340	1,270	410	410	Youngs 1960
<i>Tonina australis</i> Australian toon (Hawaii)	11	5,270	8,900	1,400	2,360	2,390	2,090	380	390	Wangard 1954
	2	2,720	3,760	600	1,100	800	750	—	—	Youngs 1960
	2	3,920	5,070	830	1,280	900	850	—	—	Youngs 1964
	5	—	—	—	—	580	440	(150) ²	(170) ²	Chowdhury and Ghosh 1958
	5	—	—	—	—	740	500	(90)	(130)	Youngs 1960
	—	—	6,400	—	—	—	—	—	—	Youngs 1960
	—	—	8,200	—	—	—	—	—	—	Youngs 1960
	4	2,060	2,790	—	—	510	430	160	170	Youngs 1960
	4	2,930	5,480	—	—	870	550	140	140	Youngs 1960

(See footnotes at end of table.)

(Continued)

Table 3—Hardness, toughness, and compression properties of small clear specimens of wood from 16 Hawaii timber species and six imported woods used in Hawaii, continued

Species and source of wood	Trees tested	Compression parallel to grain		Compression perpendicular to grain stress at proportional limit	Maximum shear strength	Hardness		Toughness		Sources
		Stress at proportional limit	Maximum crushing strength			End	Side	Radial	Tangential	
	No.	Psi	Psi	Psi	Psi	Lb	Lb	In-lb	In-lb	
<i>Tristania conferta</i>	19	4,410	5,650	960	1,650	1,580	1,760	—	—	Bolza and Kloot 1963
Brushbox (Australia)	19	5,130	9,270	1,270	2,480	1,970	2,040	—	—	
<i>Pseudotsuga menziesii</i>	—	3,130	3,860	440	930	510	500	150	200	USFPL 1955 ³ ; Youngs 1960
Douglas-fir (W. Coast)	—	5,850	7,430	870	1,160	900	710	140	200	
<i>Sequoia sempervirens</i>	16	3,700	4,200	520	800	570	410	(60) ²	(110) ²	USFPL 1955; Youngs 1960
Redwood (old-growth) (Calif.)	16	4,560	6,150	860	940	790	480	(50)	(80)	
<i>Thuja plicata</i>	15	2,470	2,750	340	710	430	270	—	—	USFPL 1955
Western red cedar (W. Coast)	15	4,360	5,020	610	860	660	350	(40) ²	(70) ²	
<i>Shorea negrosensis</i>	5	2,500	3,880	510	970	590	630	—	290	Lauricio and Bellosillo 1963
Red lauan (Philippines)	5	3,410	6,020	680	1,330	790	740	—	240	
<i>Dipterocarpus grandiflorus</i>	5	2,560	4,050	650	1,070	820	870	—	240	Lauricio and Bellosillo 1963
Apitong (Philippines)	4	4,820	8,730	1,130	1,760	1,660	1,500	—	280	
<i>Quercus alba</i>	20	3,090	3,560	830	1,250	1,120	1,060	—	—	USFPL 1955
White oak (Central states)	20	4,760	7,440	1,320	2,000	1,520	1,360	—	—	

¹ Includes *E. bicostata* and *E. St. Johnii*.

² Specimen size of figures in parentheses 5/8 by 5/8 inches tested over 8-inch span.

³ USFPL = U.S. Forest Products Laboratory.



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AN ALGORITHM TO HELP DESIGN FIRE SIMULATION AND OTHER DATA BASE WORK

Romain Mees

The simulation of fire behavior has become a valuable tool in wildland fire control. To support the simulation, large quantities of data representing local fire conditions must be developed, along with computer programs to manipulate the data and make them available for use. Both the data and the associated programs are usually referred to as the *data base*.

This report describes an algorithm that can be used in simulation models and may also prove helpful in related data base work. The method proposed is an application of well-known principles to the problem of computer simulation. Elements of the method have been successfully used in other areas of computer applications (Merrill 1973).

In a computer simulation run, the efficient and correct location of fires within certain types of boundaries, such as fuel, damage class potential, seen areas of a lookout or aircraft patrol, and equipment "exclusion" area, is essential. Information on the relation of the fire location to fuelbreak or area of modified fuels is also necessary. If, during the simulation, the fire location is found to be inside the modified fuel area, parameters of modified fuel and fire spread must be used to continue the simulation.

For illustration, we may assume that the aim is to determine the relation of the fire location to fuel type. A National Forest can be divided into fuel zones, as shown by letters A, B, C, D, and E in *figure 1*. In the forest being considered, some of the fuel zones are entirely contained within others. As a fire spreads through a given area during a simulation, the problem is to



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REPORT PSW-9 /1974

Mees, Romain M.

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The data necessary for fire simulation may be made available through an algorithm based on tracing of boundaries composed of straight-line segments. Useful assumptions are that if a closed boundary does not contain a given point, then any other closed boundary contained within the former one does not contain the location; and that a given location will be contained in a closed boundary if the number of intersections of a finite line segment, drawn from the location to a known point inside the closed boundary, is even. The method described is similar in accuracy to existing alternative methods, and may have advantages. It may also be useful in other types of data base work.

Oxford: 43-015.5

Retrieval Terms: Fire models; simulation.

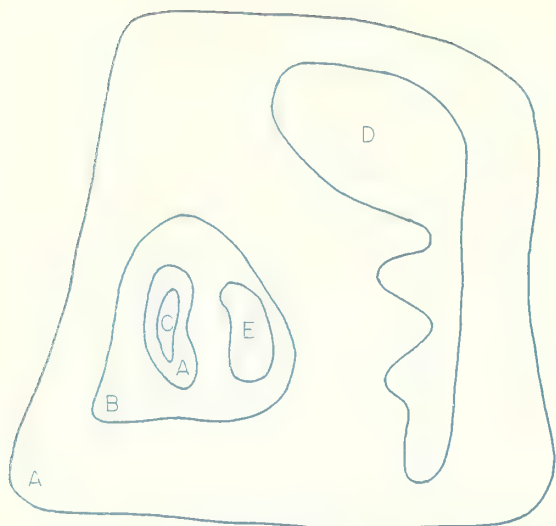


Figure 1—Fuel zones A, B, C, D, and E on a National Forest.

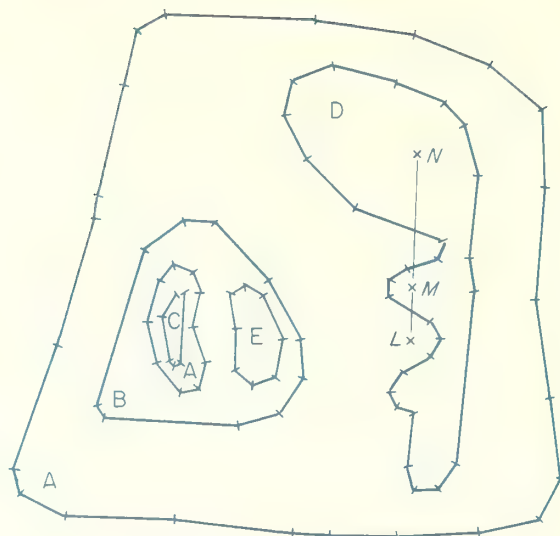


Figure 2—Digitized fuel boundaries.

determine the initial location of the fire and selected points of the expanding fire perimeter within the various fuel zones and to determine the fuel type and other associated parameters as a function of fire location.

The initial step in recording the data consists of associating the variable interest (fuel type) with location by digitizing (recording) grid points (X , Y) and the associated variable Z , to form the triplet (X , Y , and Z), in which X represents the longitude, Y the latitude, and Z the value of the variable.

At this point, two options are available:

1. Record enough grid points (X , Y , and Z), and write the associated computer programs to interpolate between grid points.
2. Trace the boundary of each zone and record points (X , Y , and Z) at selected intervals along the boundary, which is thus approximated by consecutive straight-line segments.

The same linear error is inherent in both methods, unless an interpolation scheme of a higher order is used in the first method. The choice between the two methods in a particular situation will depend on the amount and kind of data to be handled. Both methods have advantages and both have their place in simulation and data base work.

The fuel boundaries (fig. 1) can be digitized (fig. 2). Each line segment is represented by two (X , Y , and Z) triplets, and $(N + 1)$ points are needed to describe a boundary consisting of N sides.

To determine if a fire location is in or outside a given fuel zone (fig. 2), apply these principles:

1. If a closed boundary does not contain a given fire location, then any other closed boundary contained within the former one does not contain the fire location. Use of this fact in procedures for both storage and access of data on any computer system can minimize computation and access time.

2. A given fire location will be contained in a closed boundary made up of line segments if the number of intersections of a finite line segment, drawn from the fire location to a known point inside the closed boundary, is even. If the total number of intersections is odd, the location in question will be outside the boundary enclosing the area of interest. For example, if a known point N is inside the fuel area D (fig. 2), the number of intersections with the boundary of area D would be 2 for the point M and 3 for point L .

Computer programs based on the above two principles have been combined with the output of a digitizer at the Pacific Southwest Forest and Range Experiment Station's Forest Service Fire Laboratory, Riverside, California and one used to support data base work for the FOCUS program. FOCUS (Fire Operational Characteristics Using Simulation) is a model being developed at the laboratory to predict probable consequences of available alternatives in fire planning (Storey 1972).

The computer programs are written in Fortran for operation on the IBM 360 computer and are independent of the type of digitizer used. Copies of the programs are available upon request from the Director, Pacific Southwest Forest and Range Experiment

Station, P.O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

The following examples serve to clarify the application of the algorithm and indicate its accuracy.

For the example illustrated in *figure 3*, 10 zones of interest, composing a square, were established. If all 10 types are considered as a unit square, then the area of each zone is:

Zones:	Area	Percentage
A	0.33984	0.33545
B	.15234	.1531
C	.07421	.0731
D	.01953	.0191
E	.15234	.1535
F	.11718	.1191
G	.02343	.0238
H	.00390	.0035
I	.08593	.08729
J	.03107	.0320

A random set of 20,000 (X and Y) points ($0 \leq X \leq 1$, $0 \leq Y \leq 1$) was generated. Each point was then determined to be in one of the 10 zones, using the algorithm described here, and many of these points were checked individually for accuracy. As a

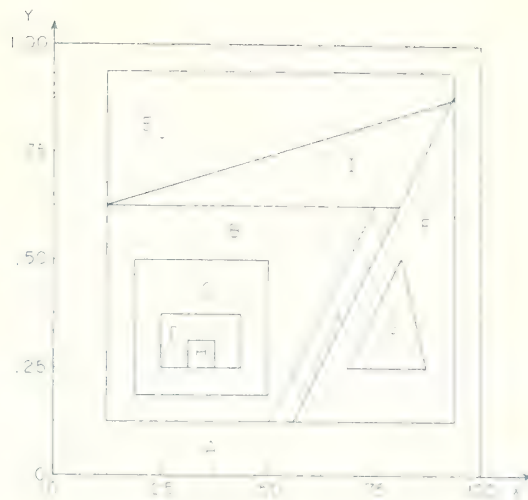


Figure 3—A unit square consisting of 10 distinct zones.

further check on the algorithm, the percentage of points falling within each zone was computed.

In an application of the technique (*fig. 4*), the 30 closed boundaries represent the seen areas of a lookout on a National Forest. Illustrated are the location of the lookout, a known inside point within each closed boundary, and the fires found inside the seen areas of the lookout.



Figure 4—Seen areas of a lookout on a National Forest illustrate the application of a data base program in computer simulation.

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Wildland Resource Information System: user's guide

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This user's guide provides detailed information about how to use the computer programs of WRIS, a computer system for storing and manipulating data about land areas. Instructions explain how to prepare maps, digitize by automatic scanners or by hand, produce polygon maps, and combine map layers. Support programs plot maps, store them on tapes, produce summaries, and perform housekeeping tasks.

Oxford: 624:U681.3:(084.3)

Retrieval Terms: timber management; wildland management; resource use planning; computer programs; map compilation; WRIS; management information systems.

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PREFACE

The Wildland Resource Information System (WRIS) is a computerized system for storing and manipulating data about land areas. The resource manager defines a geographic area by drawing a boundary around it on a map. In nature, such boundaries are irregular in shape. We retain their shapes within the system by representing them mathematically as multiple-edged polygons. *Polygons* are the fundamental building blocks of WRIS. They can represent timber stands, soil types, alternative treatments, and many other categories. WRIS has so far been used mostly for timber management; therefore examples and terminology in this report are taken from that activity. But the system can be put to work in other fields—even those outside of forestry.

A group of polygons forms a *map*. The mosaic of polygons must exhaust the surface area, but polygons must not overlap each other. All polygons on one map must be from the same *layer* (sometimes called an *overlay* by other workers). The layer can represent one kind of attribute, such as timber type. Other layers may be constructed, defining different attributes of the same ground area. To handle combinations of attributes, WRIS can overlay any two layers.

The attribute of a polygon is expressed as a *label*, consisting of from 1 to 36 characters. Each polygon must have a label attached to it. A label is not unique—it may occur many times on a map, once for every polygon containing the same attribute. The polygons on a map are assigned unique serial numbers, called *item numbers*, for identification purposes.

WRIS can be applied to an entire National Forest by dividing the Forest into townships (quadrangle sheets would be better) and by processing the maps as separate units. Each layer on a township map is drawn separately with inked lines on 24- by 24-inch (610 mm by 610 mm) paper by using a scale of 4 inches per mile. (Other scales and smaller map sheets are possible.) Then we scan it on a microdensitometer with a grid spacing of .024 inch (.61 mm). Our scanner requires transparencies no larger than 9 inches (229 mm) on a side, so the map needs to be reduced photographically.

The scanning operation stores the map in digital form on magnetic tape. This tape is condensed by a computer program (FREQTb) which also prints out the grid so it can be checked for errors. The grid consists of zeroes and ones: zeroes for the areas between lines, and ones for the points falling on polygon boundary lines.

The POLLY program then converts this grid into a file of polygons and attaches a label to each. When this is done for each layer on each township, a complete data base becomes available for a Forest. Other programs are used to combine layers (MOSAIC), accumulate acreage totals (TALLY), and draw the maps on a digital plotter (CHART).

If a map sheet is extremely simple, containing few boundary lines, most of the scanned points are zeroes. It is more efficient to hand digitize this kind of map and to process it through the HANDY program instead of using FREQTb.

WRIS was developed by the Station's research unit investigating measurement and analysis techniques for management planning. This User's Guide provides detailed information about how to use the computer programs of the system. For a fuller description of the development and characteristics of WRIS and for production information, see the companion report *WRIS: A Resource Information System for Wildland Management* (USDA Forest Service Research Paper PSW-107). Copies are available upon request to:

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The WRIS computer programs are also available upon request. They will be copied on a magnetic tape, to be supplied by the requestor. Before sending the tape, the requestor should contact this Station (Attention: Computer Services Librarian), at the above address, and give the tape format desired.



1. PREPARING MAPS

Preparing maps correctly is the single most important step in the digitizing process. Eliminating errors at this step has a greater impact on cost than doing so at any other stage. These two sources of errors can be eliminated: poor ink line quality and logical map errors.

Ink lines should be of uniform width and uniform density. Moving the pen too rapidly along a straight edge when inking straight boundaries produces a thin, weak line. A good quality inking job can completely eliminate the need to make corrections in later stages.

The most common logical errors that can be eliminated at this stage are polygons without labels and two different labels in one polygon. The latter error may occur because the size and shape obscure the fact that it is one polygon. It may also occur because the line separating two polygons was not inked.

Maps to be digitized with a scanner must be specially prepared. Draw in ink the polygons to be digitized. They must be nonoverlapping and completely fill the area to be digitized. Have only one layer of information per map; for example, one map for timber-type, one for management constraints, and one for administrative boundaries. To have polygons fill the area assign a special label to all areas which are not of interest. This step is critical for finding all errors during the editing process. The map must also be free of islands (fig. 1). Remove by connecting them to the "mainland" in two separate places (fig. 2). Eliminating islands creates new polygons. These must be labeled with the same label as the polygon they were split from. The new polygons should be at least large enough for a label to be easily printed inside.

All the maps on the Stanislaus and Eldorado National Forests were drawn with a #2 rapidograph pen. Write all other information on the map, such as polygon labels, control point numbers, or geographic coordinates with a non-photo blue pencil.

No special preparation of maps is needed for the hand digitizing process. However, comments about logical errors still apply.

2. DIGITIZING A MAP WITH A SCANNING DENSITOMETER

2.1 Equipment

In digitizing with scanning densitometer the optical density of a map is measured at every point. For the inventories of the Eldorado and Stanislaus National Forests we used a Photometric Data Systems PDS-1010.^{1/} Relatively slow but accurate, this flat-bed densitometer uses orthogonal lead screws and stepping motors to provide a raster scan of transparent material. Output is a 10-bit density for each spot in the raster. These densities are written on magnetic tape at 556 bpi. The 10-bit density provides a gray-scale of 1024 levels. The scanner bed has a 9-by 9-inch (229 mm) scan area. To accommodate the bed size and the need for using a transparency, a photographic reduction negative is scanned rather than the original map. Therefore, the user has wide choice of map size and material.

2.2 Aperture and Spacing Alternatives

The scanner can make a density reading at any grid spacing which is a multiple of 2 or 3 micrometers. The scanner can use one of 20 apertures (size of spot measured) ranging from 3.5 to 396.67 micrometers in diameter. In addition, the reduction factor used in making the negative can be varied. Ink line width on the original map can also be varied.

The optimum combination of spacing, aperture, reduction, and line width is influenced by four major interrelated factors: map size, map detail, scanning time, and computer processing time. A loss in efficiency due to a change in one factor can be partially offset by changes in the other three.

1. Map size: The larger the map the longer it takes to scan and process the data for a given level of detail. Spacing, apertures, and line width can be increased to speed up processing if map detail permits.

2. Map detail: Spacing and aperture cannot be larger than the distance between the closest lines which must be recognized as separate, times the reduction factor. Line width times reduction factor must also be equal to or larger than spacing and aperture.

^{1/}Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

3. Scanning time: Scanning time is a function of the length of a row in micrometers and the number of rows. Typical scanning times for 24- by 24-inch (610 mm by 610 mm) maps run from 10 to 13 hours. Therefore, use the maximum reduction factor possible.

4. Computer processing time: Processing time is almost wholly a function of the total number of density readings. Therefore, use the widest spacing possible consistent with the requirements of map detail. Spacing can be up to 10 percent wider than the aperture.

We found that a spacing of 60 μ m, an aperture of 56 μ m, a 10X reduction factor, and #2 rapidograph pen lines provide good results. This combination is for 1:15840-scale and 1:31680-scale maps and for photographic equipment with a maximum reduction of 11X. The capability for greater reduction might have changed the parameters.

Use different weights in assessing optimum combinations if the scanner has different operating characteristics. For example, many high-speed scanners have only three apertures and equivalent spacings. The scanning times, however, run from 2 to 10 minutes, so maximum reduction is not needed. Select a convenient aperture and spacing and vary the reduction factor to suit map detail.

2.3 Photographic Reduction

It is not necessary to obtain an exact reduction factor. Scale control is obtained through control points rather than by calculation of a sequence of enlargement and reduction factors. Almost any high contrast copy film intended for line drawings can be used for making the reduction negative. A combination of transmitted and reflected light produces the best results. The transmitted light increases the contrast between ink lines and background. The reflected light is needed to wash out the non-photo blue labels.

2.4 Scanning Procedure

Place the negative on the scanner bed so that the scan starts in the upper left hand corner of the scan area and the first scan line is left to right across the top. In setting up the X and Y scan limits, be sure to include as few extra

readings as possible. The extra readings increase the volume of data and thus the cost of processing.

The machine settings we used for the Stanislaus and Eldorado National Forests maps to get a spacing of 60 μ m and an aperture of 56 μ m were: set upper and lower aperture turret at E, set upper and lower magnification at 2, set micrometers per step at 6, set steps per reading at 10, X-axis motor at B, and Y-axis motor at E. (See also Appendix C.)

2.5 Selection of Density Threshold

To extract polygons from the scanner data, the grid of densities (fig. 3) must be converted to a binary map, which is a grid with ones for lines and zeros for spaces between lines. To convert, all densities below a threshold are set to one and all densities above that threshold to zero. When a scanner tape is read, all or a sample of the densities are used to construct a frequency table. The mode, the most frequent class, represents the density of most of the background of a map. The mode is used to calibrate the densities for differences in exposure and development in making the negative.

The threshold is set by the density adjustment factor read into the program FREQTB (fig. 4). The density adjustment factor is the number of density levels the threshold is below the mode (figs. 5,6,7). The larger the density adjustment factor the lower the threshold and thus the fewer ones to represent lines. A particular density adjustment factor should be constant for one batch of maps and negatives. A new batch may require changing the adjustment factor. Tying the threshold to the mode takes care of minor differences within a batch. Edit first FREQTB printout for a batch of maps before making any more runs. (See section 4.1 on editing a binary map.) If the lines have too many gaps, (ADDS) the threshold is too low.

To raise the threshold, lower the density adjustment. If there are too many places which should be gaps and are not (DELETES), the threshold is too high. Lower the threshold by enlarging the adjustment factor. The absolute number of ADDS and DELETES is used to judge the threshold. About twice as many DELETES as ADDS is a good balance to strive for (figs. 8, 9, 10).

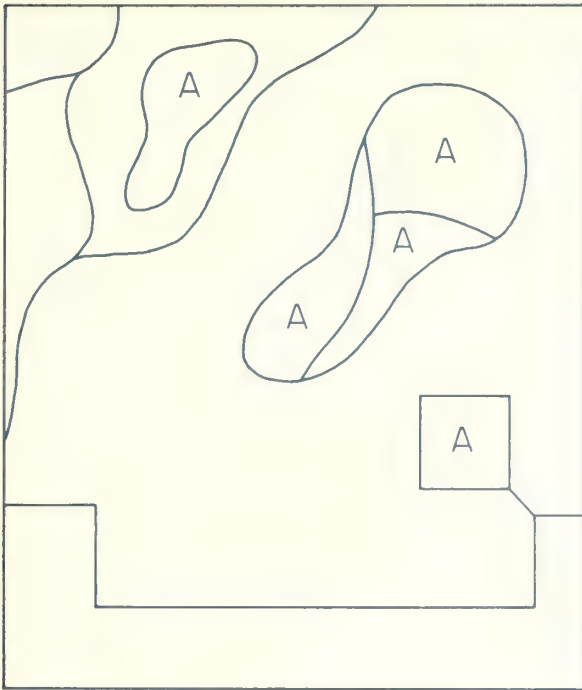


Figure 1--Polygons labeled A are considered islands by WRIS.

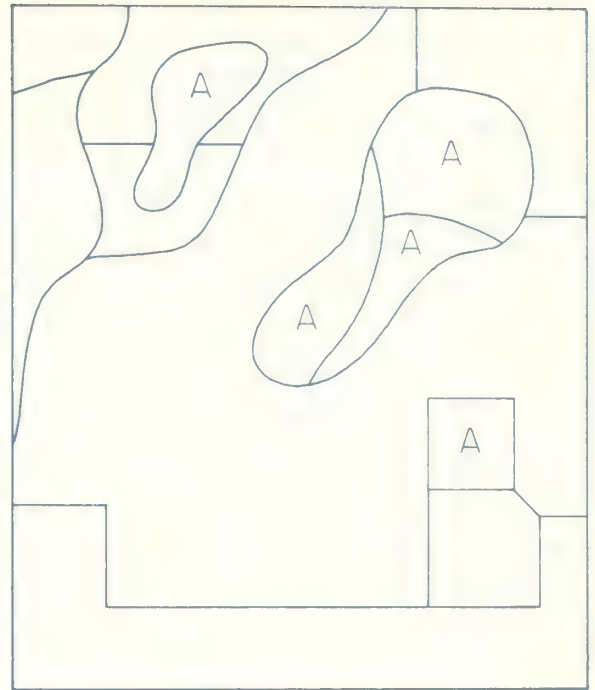


Figure 2--The islands in figure 1 have been removed by adding connecting lines.

Figure 3--Densities of a two-digit scan of a portion of a map.



Figure 8--FREQTB printout of binary map in figure 5.



Figure 9--FREQTB printout of binary map in figure 6.

2.6 Converting Binary Map (FREQTb)

FREQTb reads a microdensitometer tape and tabulates the frequency of each density level from 0 to 63, using the six high-order bits of each density reading. Each six-bit value is converted to a one, if below, or a zero, if above an established threshold. FREQTb computes this threshold by subtracting the DENSITY ADJUSTMENT FACTOR from the mode of the density frequency table. The resulting matrix of binary values duplicates the scanned negative, with ones representing lines (low density) and zeros representing the background (high density). The one/zero values are written compactly on tape for use by PØLLY. To allow manual editing, the binary values are also printed.

FREQTb will process one or more files (i.e., maps) from one scan tape, with output on one or more tapes as specified by the user.

Input Cards:

1. System cards.

2. Input unit description, containing unit designation, number of files (good and bad) on the input tape (FILES=n), and number of files (if any) to be skipped at the beginning (SKIPS=n).

3. DENSITY ADJUSTMENT FACTOR for first map. (See Section 2.5.)

4. Header record (forest, map, and layer) and output unit for first map.

If two or more maps are to be processed from the input tape, items 3 and 4 may be repeated for each map. They must be in the same order as the scanning was done, as FREQTb does not rewind and then search the tape for subsequent maps. Five minutes of Univac 1108 computer time is adequate for a FREQTb job on a map of 1000 scan rows and 1000 readings per row. This size map would produce about 180 pages of output (less if map has large blank areas).

Sample input deck:

```
@ RUN JØEDØE, 123456,5,200
@ CTL CLS=N
@FH ASG A=1234
@W ASG B=5678
@ ASG X=9876
@ CUR
IN X
TRI X
@ XQT FREQTb
```

```
INPUT UNIT=A$
FILES=4;SKIPS=0$
DENSITY ADJUSTMENT FACTØR=22$
FØREST=ELDØRADØ; LAYER=TIMBER;MAP=17;
ØUTPUT UNIT=B$
@ FIN
```

3. DIGITIZING MAPS BY HAND

The computer time required to process an automatically-scanned map does not depend on its complexity. The same number of density readings must be taken on a simple map as on a "busy" one. But on a simple map, nearly all readings are zeroes. Therefore, such a map is relatively expensive to process by the scanner method, considering the small amount of information collected.

A better method is to digitize only the lines--and do so manually. For this we employ a hand-guided digitizer and a program that processes its output into the same form produced by FREQTb. Because of its limitations, we consider this an alternative rather than primary method. Users should choose the scale and area of their maps in such a way that most of the work can be efficiently processed by the scanning method, leaving only a small part to be hand digitized.

3.1 Equipment

For hand digitizing, we use a Bendix Datagrid digitizer. It has a resolution of 0.01 inch (.25 mm). Move the "cursor" over the map by following the inked lines. The cursor senses its coordinate positions as it moves, and these x-y coordinates are recorded on magnetic tape.

3.2 Digitizing Procedure

Tape the map to the digitizer surface. Move the cursor over all lines to be recorded. All boundaries must be closed. A boundary may be recorded in as many pieces (records) as necessary as long as no gap is left between pieces. A small overlap is desirable. So is a small overrun at T-shaped intersections. A straight line is best done in Point Mode, recording only the end points. (For our purposes, Point and Line Modes are interchangeable.) A straight line done in Point Mode looks better when plotted. Do not digitize the control points.

3.3 Converting to Binary Map (HANDY)

The HANDY program receives as input the tape written by the Bendix digitizer.

Output is a tape that appears the same as the output of FREQTB: a map scanned on a grid having a spacing of .02 inch (.5 mm). HANDY constructs a grid of that spacing, presets all of its points to the value 0, and then changes to 1 all points that any digitized line passes over. Thus, overlapped segments are merely redundant. Any spur-like overruns are pared off during later processing.

Two cards are required input. The first is a "header record" containing just the name of the input unit bearing the Bendix tape. The other is also a header record, for our output tape. It must contain the unit name, and Forest, Map, and Layer.

Here is a typical input deck:

```
@ RUN RUSS,583301,1,300
@ CTL CLS=N
@ ASG A=1234
@WH ASG B=5678
@N CUR
IN X
TRI X
@N XQT HANDY
INPUT UNIT=A $
OUTPUT UNIT=B; FOREST=ELDORADØ;
MAP=1; LAYER=TIMBER $
```

4. PRODUCING A POLYGON MAP

Once a map has been digitized and condensed to binary form, it is necessary to generate a file of polygons from it and to attach labels to the polygons. A considerable amount of editing is necessary to correct errors and noise.

4.1 Editing the Binary Map

The general procedure is to flag all errors on the computer printout. Then record all corrections on data forms for keypunching. The printout is a series of vertical strips, commencing with the left-most edge of the map.

4.1.1 Editing Guidelines

Visually scan each strip, comparing it with the map or a photo of the map for errors. Careful editing of the printout at this stage will save considerable time and cost later. Correct each error by circling each "Ø" to be deleted with a red pencil and circling with a blue or green pencil each space where an "Ø" is to be added. Put a check in the right margin if one or more corrections occur in a row. These checks will help to avoid

omissions at the data recording stage. Blocks of 10 lines are not printed if they are blank.

Follow these rules for adding or deleting "Ø's":

1. Fill in gaps in lines with as few points as possible (fig. 11).
2. Open the gaps between close lying lines (fig. 12).

Hints for editing:

1. Construct "rulers" consisting of the column heads for each strip. Insert rulers in the printout at the beginning of each strip. This helps to minimize the error of forgetting to change rulers at the beginning of each strip. Column numbers are printed at the beginning of each strip. Row numbers are printed along the right side of the strip. The strip number is printed in a column to the right of the row number.
2. Visually follow each string of Ø's looking for gaps in lines, small polygons, and areas with a high density of Ø's. These gaps are potential areas for corrections. Two Ø's are considered connected if they are in adjacent spaces either vertically, horizontally, or diagonally. Look particularly for polygons with only a few interior cells. Such polygons are hard to spot when they are formed by diagonal connections. Two kinds of features which can cause extra small polygons are sharp 180° turns of a boundary and two parallel boundaries which are close together on the map but not separate on the printout.
3. Since each addition and deletion must later be recorded and keypunched, try to keep corrections to a minimum.
4. Two polygons connected by a narrow neck on the map may have two different labels. Therefore, take care when correcting this kind of gap.
5. The first two columns on each strip are repeats of the last two columns of the previous strip. These columns almost eliminate the need to refer to previous strips while making corrections. Any corrections to a repeated column need only be made once.
6. Ignore stray Ø's which may occur due to portions of labels or specks of

dirt that were photographed. A computer program will "dissolve" them. It also dissolves any piece of a line that is not part of a loop. This is all right if the line came from a smudge but will be an error if it is due to a gap in an inked line.

7. It is highly desirable that the printout should be edited twice, each time by a different person. Usually omissions will be found and the list will lengthen.

4.1.2 Recording Error Corrections

Record the row and column numbers where the control points appear on the binary map. These are the GRID CONTROL POINTS in the PØLLY input deck. Record them in clockwise order starting with the lower left corner.

Next record the "add" and "delete" corrections marked on the FREQTB printout. For convenience in handling the card decks later, start the recording with a card which identified the adds and deletes; examples: 'ADDS MAP 30' or 'DELETES MAP NUMBER 26'. It is helpful to start recording deletes at the top of a separate sheet. Each strip has a ruler for recording column numbers. Look for check marks in the right margin opposite rows needing correction. Record adds and deletes by row and column on data forms; examples, 5, 62, 10,453. For convenience in subsequent editing, start each line with a row entry and end with a column entry followed by a comma. Leave unused columns blank. In this way an item will not be split between lines, and no error will occur if the order of the cards is changed. Long consecutive lists of items in one row or one column may be added or deleted by the following short-cut method: [R,C1ΔC2], or [R1ΔR2,C]. (See also Section 7.33.)

4.2 Recording Polygon Labels

4.2.1 Setup

To record the x-y position of the labels, establish axes. The length of each axis slightly exceeds the largest map dimension expected. The vertical or "north-south" direction is designated as the y axis. The map is positioned within the right angle formed by the x-y axes so that the control points (and all points) will be positive, non-zero integers. The x and y distances from the origin in hundredths of an inch are recorded as explained in the section on map control points. (7.3.2)

4.2.2 Symbol Transcription

If both upper and lower case letters are used in a map, a translation into a format acceptable as computer input is required. Rules and examples are described in Appendix A.

The Mylar maps supplied by the contractor for the Stanislaus and Eldorado National Forests had standard Region 5 forest-type classifications and therefore require transcription of some symbols.

4.2.3 Label Recording

Start recording labels and their x-y position on a new line of the data form. Select a coordinate position that is roughly centrally located in the polygon. Use a non-photo blue pencil to check off each label as it is recorded. An entity consists of a label followed by its x and y position. Entities are separated by a comma. The last entity is followed by a dollar sign. Within the entity, the three parts are separated by one or more blanks. The x and the y coordinates are in units of 0.01 inch. Thus, 24 inches from the origin is written as 2400.

The data is written as one long "stream;" that is, the end of a line on a data form has no significance. If an entity is not complete when the last column is reached, simply continue on the next line. Just one caution, however. It is easy to forget that a blank is a significant character (separator). There is a tendency to forget recording the blank when it falls just after the last column and thus in column 1 of the next line.

4.2.4 Master Label Accumulation

When complex labels such as the timber labels shown in Appendix A are used, care must be taken to eliminate typographical and logical errors from the label input deck. PØLLY, the polygon extracting program, checks each label against a master label list. A message is printed if the label is not on the master list. For some layers an exhaustive list of labels is easy to make. It is not difficult to completely list counties, ranger districts, or even management constraint classes. However, there may be over 1,000 codes used out of a possible million or more codes in the system used for the timber layer on the Stanislaus and Eldorado National Forests. In this situation WRIS uses label decks and

the program SIGNAL described in a following section to construct a complete master label list.

The process is started by using the ADD ITEM control card to put the label input deck of the first map into the master label file. The labels can then be sorted and printed. This sorted list of labels should then be very carefully edited to make sure that the labels follow all the rules of the coding system. Any incorrect labels can be deleted from the list by using the DELETE LABELS control card. The corrected labels are then added to the list. The next deck of labels can then be checked against the master label list by using the CHECK LABELS control card. All labels which were not in the original deck will be flagged in the printout. These should all be checked carefully and any errors corrected in the card deck. This deck can then be added to the master list with the ADD ITEM control card. Duplicates of labels already on the master list will be ignored. Each label input deck is processed in this way; that is, by carefully checking any new labels before adding that deck to the master label list.

When all decks have been processed the master label file will contain a complete list of all labels which occur at least once on a set of maps. Any new or changed labels which are put in the label deck during editing will be flagged by PØLLY. This procedure provides an additional chance to check the label against the coding rules. If the label is correctly constructed it can be added to the master label list.

4.3 Extracting Polygons from Binary Map (PØLLY)

PØLLY corrects a binary map by using the ADDS and DELETES. It then extracts polygons from the binary map by using the label locations as starting points (see Section 4.2.3). All the polygons extracted are written on the output tape. PØLLY will run a batch of jobs when there is a series of control cards following the XQT card.

Input Cards

1. System cards.

2. Header record (forest, map, layer, geographic control points, map control points, grid control points, location, scale) and input unit for the binary map.

3. Header record containing only the output unit.

4. Correction cards for binary map from editing of FREQTb printout.

5. Master label file name.

6. Label deck.

Example Input Deck

```
@ RUN JØE,123456,3,100
@ CTL CLS=N
@ CTL SYS=A
@ ASG A=1234
@W ASG B=5678
@ ASG X=3477
@N CUR
IN X
TRI X
@N XQT PØLLY
INPUT UNIT=A; FØREST=ELDØRADØ; MAP=236;
LAYER=MANAGEMENT; LØCATION=T12N R16E;
SCALE=31680;
GEØGRAPHIC CØNTRØL PØINTS=39:30:0.0,
120:15:0.0,39:37:30.0,120:15:0.0,
39:37:30.0,120:07:30.0,39:30:0.0,
120:07:30.0;
MAP CØNTRØL PØINTS=100,100,102,1322,
1380,1318,1318,100;
GRID CØNTRØL PØINTS=474,2,3,3,4,494,
473,471$
ØUTPUT UNIT=B$
'ADDS MAP 236'
10,16 $
'DELETES MAP 236'
388,48, [390Δ391,45] , 392,44,393,
43, [397,44Δ45] $
FILE. (ALPHA/LABELS)
LS 300 1200, RL 600 700$
```

Limitations

Maximum number of x-y points in any polygon: 1991

Maximum number of polygons in one map: 500

Maximum number of ADDS and DELETES combined: 5000

4.4 Editing PØLLY Printout

Printout of a normally terminated PØLLY run will consist of these sections:

1. Header record input from cards.

2. Header record resulting from tape header record merged with card input record.

3. Output unit number.

4. List of corrections for binary map.

- a. Additions input cards
- b. Sorted list of additions
- c. Deletions input cards
- d. Sorted list of deletions

5. List of labels.

- a. Label input cards
- b. Sorted list of labels

6. Output header record.

7. Local label list.

8. Detailed list of extracted polygons.

9. Summary record of number and area of polygons.

10. Confirmation of writing of output file.

For the purpose of editing, this output can be considered in two groups: Items 1-5 deal with input; items 6-10 deal with output.

The printout is organized for use in editing rather than as a record of data. Errors during input are usually recording, format, or key punch errors. There are two groups of errors: those which stop the program and those that do not. It is best to start looking at the back of the printout to see if any input errors have stopped the program. A list of fatal error messages follows:

INPUT/OUTPUT FILE SPECIFICATION ERROR i

An input or output unit number is given in the wrong place in the input card deck. If i=0 an input unit number was given where an output unit number was expected. If i=1 an output unit number was given where an input unit number was expected. (See Section 4.3 for proper deck setup.)

INPUT TAPE SHOULD BE MODE 1 BUT IS i

A file with the correct Forest, Map and Layer, but without a binary map was read. Mode of the file is i. (A binary map is mode 1, a polygon map is mode 2.)

CANNOT RECOGNIZE THE LABEL nnn

The left-hand side of a header record entity (nnn) is misspelled. (See Section 7.3.2.)

INPUT CARD ERROR

The header record card has a format error. (See Section 7.3.2.)

T00 MUCH DATA ON INPUT CARDS

The total amount of data in the header record is more than the program can handle. See the programmer responsible for WRIS maintenance.

READ ERROR WHILE READING ADDITIONS DECK

READ ERROR WHILE READING DELETIONS DECK

Both of these errors result from format errors such as missing or extra commas, extra brackets, or lack of a record terminator. See the sections on Editing the Binary Map and on Card Formats for a complete description of format.

ADDITION OUT OF RANGE ROW i COLUMN j

DELETION OUT OF RANGE ROW i COLUMN j

A row or column exceeds the maximum number of rows or columns in the map. The maximums are found in the header record labelled "SCAN ROWS" and "SCAN COLUMNS."

CARD INPUT ERROR

This message indicates a format error while reading labels. (See Section 4.2 for label format.)

ERROR READING LABEL DECK i

If i equals 4, an end-of-file was encountered while reading the label deck. The usual cause is a missing record terminator. If i is greater than 4 there are more labels than the program can handle. See the programmer responsible for WRIS maintenance.

If the P0LLY printout is not terminated by one of the preceding error messages, one of the following messages may appear in the listing of label input cards. (Processing continues after these errors.)

N0 MASTER LABEL FOUND nnn

The label nnn is not in the master label list. If nnn is not a valid label it should be corrected, otherwise it should be added to the master label list. The label is used by the program as if it were a correct label.

NO COORDINATES FOUND FOR THIS LABEL nnn

A recording or key-punching error has resulted in no coordinates being associated with the label nnn. This label is ignored for further processing.

The remaining error messages result from logical errors in the data. They are found during the process of extracting polygons. The messages will be interspersed with the detailed list of polygons. To be able to correct logical errors in the data some understanding of the thinning and polygon extracting algorithms is needed.

The thinning algorithm starts with a binary map as output by FREQTb and ends with a binary map with all lines 1 bit thick. It starts at the top of the map and looks at one row at a time. A row is scanned until a string of one bits is found. A one bit is eliminated from the string if it is not essential for maintaining a connection between one-bits in the row above or the row below. The bits in a string are examined in the following order: The bit on the left end of the string is eliminated until a connection would be broken; then the bit on the right end of the string is eliminated until a connection would be broken; finally, the interior bits are examined from left to right. When all strings in a row have been examined the program moves to the row below. The main consequence of the thinning process for the PØLLY editor is that a gap in a line causes the line to be erased down and to the right or left but not up. The erasure stops when the line meets or intersects another line.

Figures 13 and 14 show the results of thinning the examples illustrated in Figures 11 and 12. Figures 15 through 18 duplicate figures 11 through 14, but the ADD and DELETE corrections have been made.

The polygon extractor starts with a label location in the binary map. The label location is found by the program by transforming the x-y label map coordinates into row-column grid coordinates. Starting at the column of the label location, the row is scanned to the right until a line is encountered. The line is followed clockwise around the polygon. At any intersection the closest line in the counter-clockwise direction is taken. The line is followed until the starting point is reached. When a deadend is encountered the last bit in the line is eliminated, and the program attempts to continue following the line.

If the next bit back along the line is now a deadend it is eliminated. This backing up continues until a bit is found which can continue the line or until a fifth bit would be eliminated. When a fifth deadend bit is encountered in a string the program abandons the attempt to extract the polygon. If the program successfully returns to the starting point it creates an artificial deadend by filling in the row of the label location from the starting point to the label location. This artificial deadend is used to detect multiple labels in a single polygon.

With the operation of these two algorithms in mind we can describe the correction of the data errors signaled by the following error messages. Several of the error messages are followed by this label printout:

LABEL NUMBER =n, LABEL=m, X=i,
Y=j MAP LABEL=kkk

n is the position of the label in the input card deck.

m is the position of the label in the local label list

i, j is the label location in map coordinates

kkk is the label

Error messages which begin with 10 asterisks terminate processing of that polygon.

*****LABEL LOCATION OUT OF RANGE*****

When the x-y label location in map coordinates is converted to row-column in grid coordinates one of the coordinates is outside of the range 1 to "SCAN ROWS" or "SCAN COLUMNS." The label printout following this message locates the label in the card deck and on the original map so that it can be corrected.

*****THE FOLLOWING LABEL IS ON OR ADJACENT
TO A LINE*****

The label location given in the label printout that follows this message may be in error. Its location near a line may also keep other errors from being detected.

REACHED EDGE OF MAP n

The scan to the right has gone to column n and has not encountered any line. The label location in the following label printout may have been misread or recorded wrong. If the label is for a small polygon along

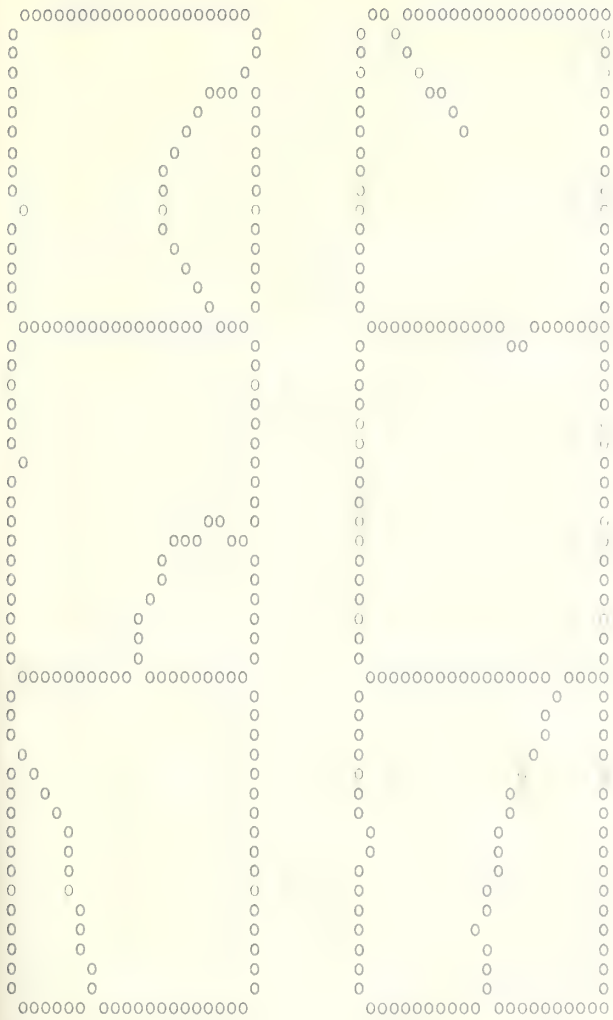
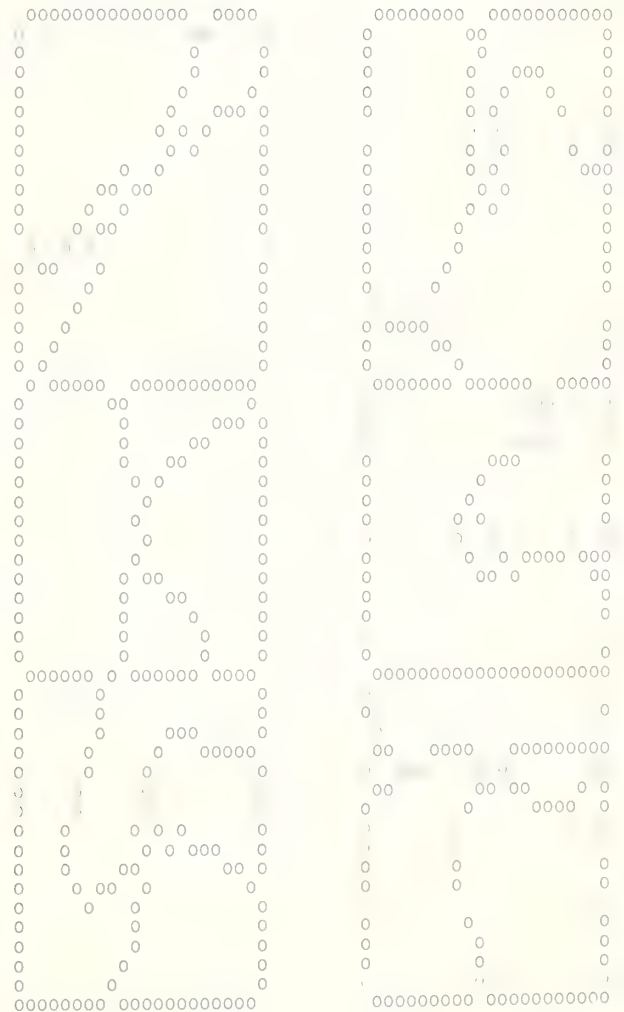


Figure 13-Results of thinning the examples in figure 11 without making ADDS.

Figure 14-Results of thinning the examples in figure 12 without making DELETES.



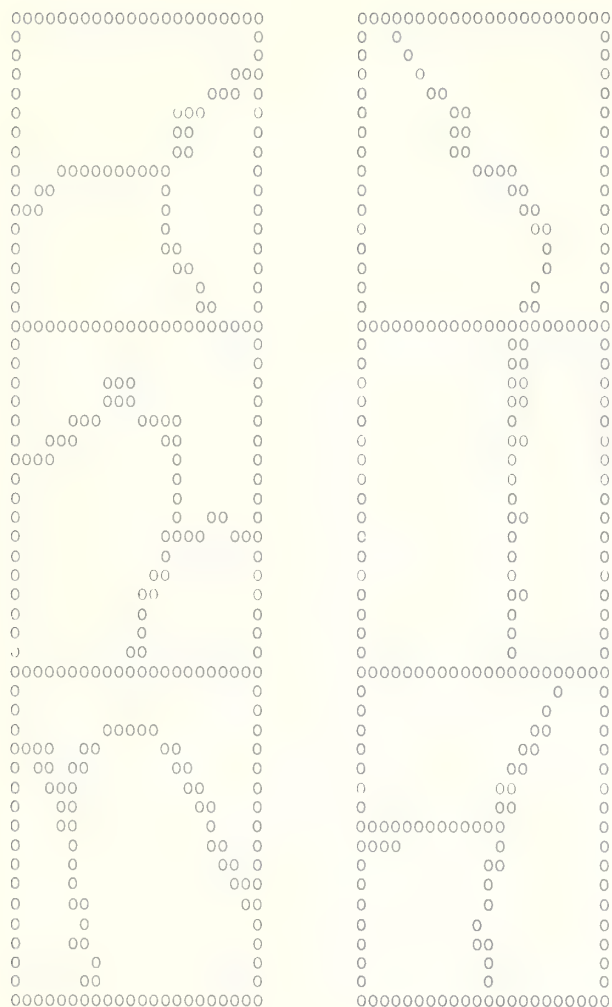
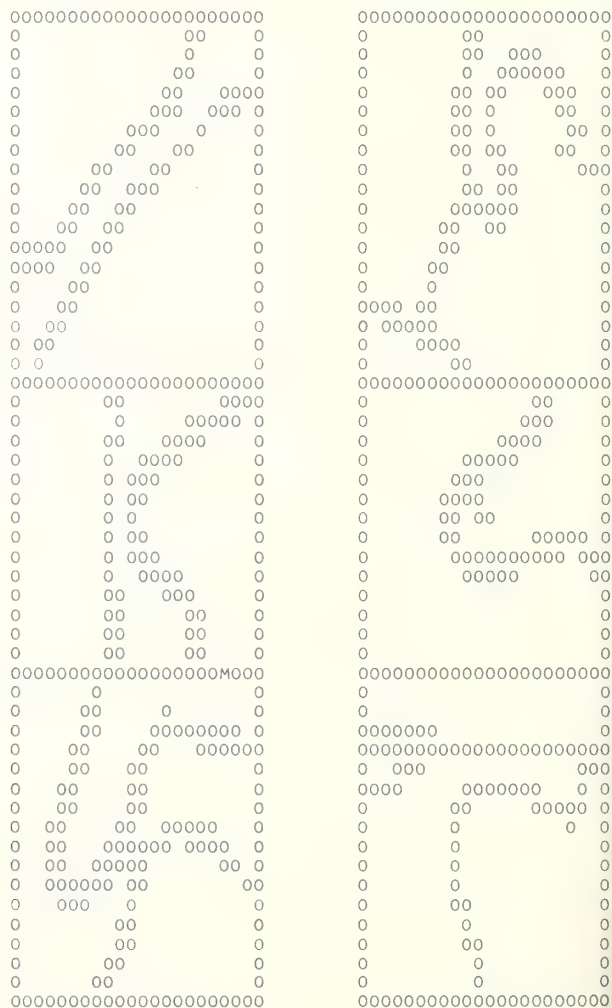


Figure 15--Results of making ADDS in the examples in figure 11.

Figure 16--Results of making DELETES in the examples in figure 12.



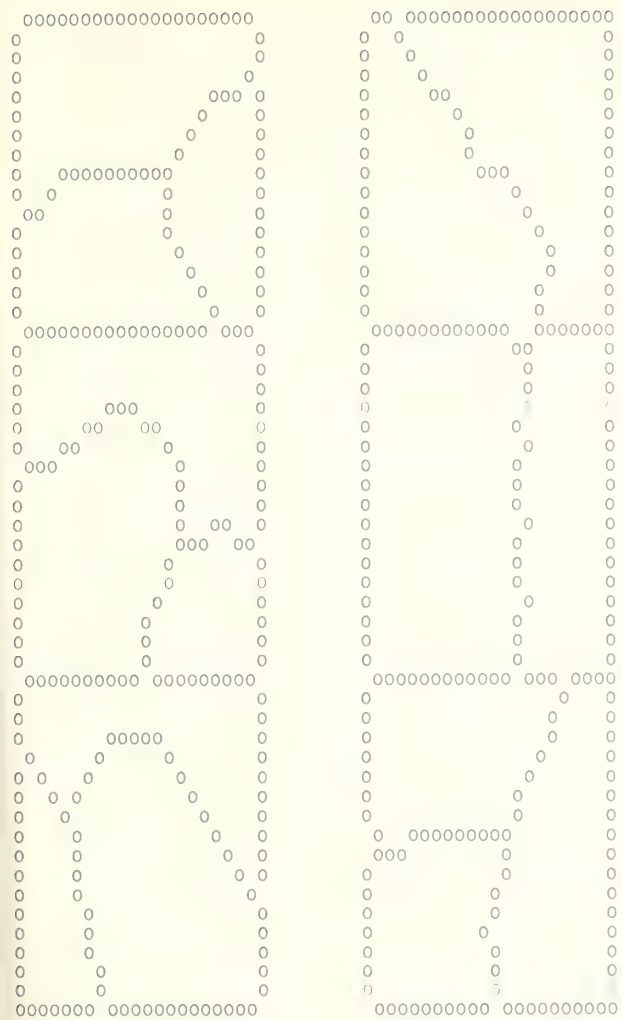
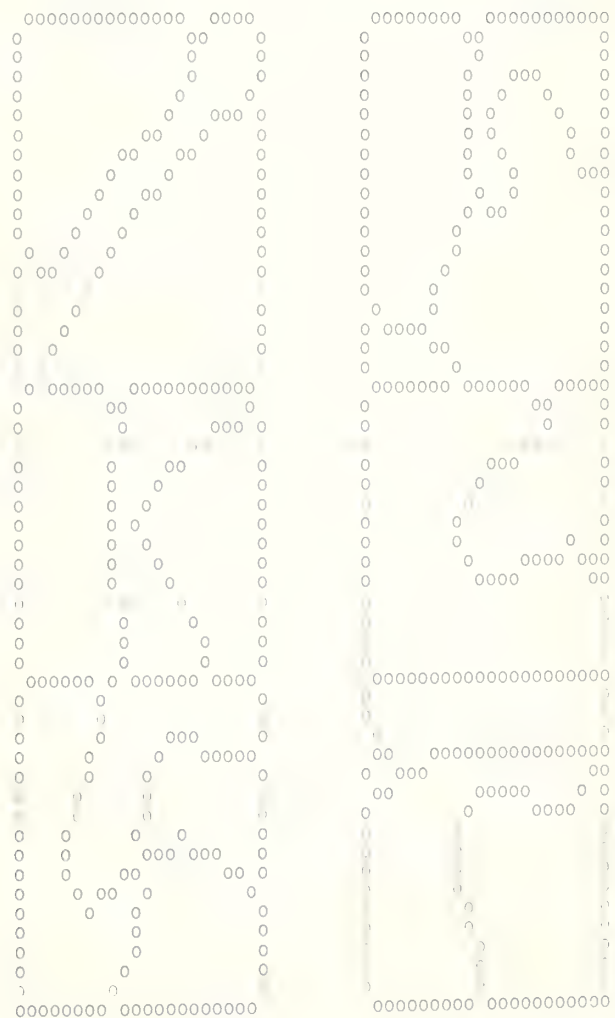


Figure 17--Results of thinning the examples in figure 15.

Figure 18--Results of thinning the examples in figure 16.



the top, right, or bottom edge a small error in either map or grid control points could put the label outside of the map perimeter.

PØLYGØN TØØ LØNG. STØPPED AT RØW i,
CØLUMN j LABEL AT RØW k CØLUMN n

The polygon has more than the maximum number of points allowed in its border (see limitations in Section 4.3). The following label printout will locate the polygon on the original map. The polygon must be cut into at least two smaller polygons by adding one bits to the binary map using correction cards. A new label must be added to the label deck for each new polygon created.

*****SCAN INTERRUPTED BY ISLAND*****

LABEL AT RØW i, CØLUMN j

The polygon boundary does not enclose the label and is therefore an island inside the polygon for which the label was intended. Find the island using the label printout which follows the error message. Eliminate the island with additions cards (see also Section 1 on preparing maps).

****DEADEND ENCØUNTERED****

DEADEND AT RØW i CØLUMN j X=x, Y=y,

PØLYGØN LABEL AT RØW i, CØLUMN j

This is followed by a label printout and one of the three following messages. If the deadend is artificial the left end is near a previously used label location. That label is found and this message is printed:

*****THE FØLLØWING LABEL IS WITHIN 5
HUNDREDTHS ØF THE DEADEND*****

This is followed by a label printout. The two labels are in the same polygon. They can be found in the sorted label list and on the original map so that the conflict can be resolved. If the two labels appear to be in adjacent polygons on the map and their label locations are correctly recorded, a gap in a line may have caused the thinning algorithm to erase the boundary between the two polygons.

If no label is found within 0.05 inch (1.27 m) of the deadend it is assumed to be a real, not artificial, deadend. In this case two 20-row by 20-column pieces of the binary map are printed. The first piece is of the original binary map with

the corrections incorporated. The second piece is the thinned map. Both pieces are centered on the deadend. For short deadends these two printouts should be sufficient for correcting the error. For more complex cases, the FREQTB printout will have to be consulted. Deadends less than 5 bits long will be eliminated from the boundary by the program and need not be corrected with delete cards.

*****MORE THAN 4 DEADENDS*****

This message is printed and processing of this polygon terminated when the deadend is more than 4 bits long.

*****DEADEND AT BEGINNING AND END OF
POLYGON*****

When a second label in a polygon is on the same row as the first label the artificial deadend is not seen as a deadend in the usual way. This message is followed by a label printout for the current label and a label printout for the label within 0.05 inch (1.27 mm) of the deadend.

At the end of the detailed list of polygons are four numbers which help determine whether all errors have been eliminated. First 'NUMBER OF LABELS READ' should equal 'NUMBER OF POLYGONS WRITTEN'. Any difference comes from not completing some polygon due to an error. The second pair of items 'AREA OF ENCLØSING PØLYGØN' and 'AREA ØF ENCLØSED PØLYGØNS' should agree within about one part in 4000. While one part in 4000 is usually much greater accuracy than the data warrants, it makes it very unlikely that compensating errors will give the appearance of an error-free map.

Occasionally, due to poor quality input or careless editing, a map will have many interrelated errors. It is sometimes difficult in these cases to trace the cause of all the errors. It is best then to rerun PØLLY with as many corrections as can be made. Many of the remaining errors will disappear and the rest will be easier to correct.

4.5 Editing Polygon File With Line Plotter

Editing a polygon file with a line plotter helps detect errors that PØLLY cannot find. Five kinds of errors can show up on the line plot. A lack of agreement between the two areas printed at the end of PØLLY is an indication that at least one of these errors is present:

1. A line that does not coincide on the plot and the map. This error is usually caused by a mistake in editing the binary map.

2. A line is on the map but not on the plot. If labels are not recorded for two adjacent polygons, their common boundary will not be plotted. If one label is not recorded and an error in editing the binary map causes one side of the polygon to be erased the polygon will be included as part of the adjacent polygon. An unrecorded label for a polygon on the edge of the map will cause part of the map perimeter to be missing from the plot.

3. A straight horizontal line on the plot is not on the map. A label is centered over the left end of the line. Its location fell exactly on a polygon boundary instead of within. PØLLY got lost trying to construct the polygon and accidentally produced this spurious line. Check the label's co-ordinates or the control points.

4. Small polygons, usually about one-tenth inch on a side are on the plot but not on the map. These are caused by an error in editing the binary map.

5. Polygons are missing from the plot. Since adjacent polygons have some part of their boundary in common with the missing polygon, it will appear to be plotted. The only clue that the polygon is absent is the lack of a label.

To edit the plot, tape it onto the top of the original map with the control points aligned as closely as possible.

Control points on the plot should all be within 0.05 inch of the control points on the original map. If the control points do not agree, re-measure the control points on the original map to help find which coordinate is in error. Usually only one of the eight readings that are off by 0.1, 1, or 5 inches. If a corner is off by as much as 1 inch PØLLY should be rerun with the correct corners and a new plot made.

Then, with the plot still on top of the map, systematically scan the plot looking for the five kinds of errors desired earlier. When all of the errors have been found, use the PØLLY printout and the original map to find the cause of all the errors. Then correct the PØLLY input deck and rerun PØLLY.

4.6 Work Flow

Preceding sections have described each step in producing a polygon file from a map sheet. The order of the sections was chosen for expository purposes. The most efficient sequence of steps, in practice, may be somewhat different. The sequence of steps given below was found to work well on maps of the Stanislaus and Eldorado National Forests. Experience with other kinds of map projects may suggest modifications to these steps.

1. Record the labels (See Section 4.2). Recording labels before any other work is done provides an additional close look at the maps and may uncover some remaining logical errors.

2. Make the negative (See Section 2.3).

3. Scan the negative (See Section 2.4).

4. Convert scan tape to binary map with FREQTB (See Section 2.6).

5. Edit the binary map (See Section 4.1).

6. Extract polygons from the binary map with PØLLY (See Section 4.3). PØLLY output should be edited and PØLLY rerun until all error messages are eliminated.

7. Plot the map using CHART (See Section 6.1).

8. Edit the plot (See Section 4.5).

9. Rerun PØLLY making corrections found from plot. Area of enclosing polygon and enclosed polygons should agree to about one part in 4000.

At this point the map is ready for use and can be processed by any WRIS program that operates on a file of polygons.

5. COMBINING LAYERS

5.1 Overlaying Maps from Two Layers (MØSAIC)

MØSAIC combines two maps representing the same area on the ground but from different layers. The result is a polygon map in which each polygon represents the area in common between a pair of polygons, one from each input map. (In mathematical terms, this overlay polygon is the intersection of the sets of points inside the two input polygons.) The label of this new

polygon is a combination of the two constituent labels. All such pairs of overlapping input polygons are processed. If both input maps completely cover a given area of land with polygons, so will the resulting map. But "slivers," or polygons of insignificant size are disregarded. By "insignificant" we mean those whose area is less than 0.0125 square inch or whose area-to-perimeter ratio is less than 1/100 (map coordinates).

The composite map can be written on tape for later use if desired. This is not necessary if all you want is a table of acreages showing the total area for each label pair. This acreage table is printed and also punched. The punched cards are for input to TALLY.

MOSAIC will run a batch of jobs for a series of control card sets following the XQT card. If one of the two input maps is from a layer named "TIMBER" we assume its labels are forest-type descriptions (See Appendix A) and we condense them into major types (Appendix B) before processing.

Input Cards:

1. System cards
2. Header record (forest, map, layer) and input unit of the first input map.
3. Header record (forest, map, layer) and input unit of the second input map.
4. Header record and output unit for output file. Include only those portions of the header record that are different from the input files, namely, Map and Layer. If you do not wish to write the output file, all you punch is "OUTPUT UNIT=NONE\$."

Example of Input Deck

```
@ RUN JOE,123456,4,50
@ CTL CLS=N
@ CTL MEM=60M, MAXCARDS=100, SYS=A
@ ASG A=1234
@ ASG B=5678
@W ASG C=4321
@N CUR
IN X
TRI X
@N XQT MOSAIC
INPUT UNIT=A; F0REST=ELD0RAD0;
MAP=216; LAYER=MANAGEMENT$
INPUT UNIT=B; F0REST=ELD0RAD0;
MAP=16; LAYER=TIMBER$
0UTPUT UNIT=C; MAP=1016;
LAYER=0VERLAY$
```

Limitations:

1. Maximum number of x-y points in any pair of input polygons and their intersection, all combined: 3000
2. Maximum number of items in both input files plus output file: 2000 (effectively, this means a limit of about 500 polygons in each input file).
3. Maximum number of times a polygon pair (one from each input file) can cross each other: 800
4. Timing: MOSAIC requires about 1 minute of Univac 1108 computer time when each input file has 50 polygons, and about 4 minutes for 400 polygons.

5.2 Aggregating Overlay Acreages (TALLY)

Tally adds up the card decks punched by MOSAIC, which contain the acreages of the overlay combination, and prints the total acreages. The totals are also punched, in the same format, so the job can be divided into subtotal steps if desired.

Input Cards:

1. System cards.
2. Forest name, followed by a dollar sign.
3. Location, followed by a dollar sign. This is used for visual identification only.
4. Master label list for each layer. The layers come in alphabetical order. A master label list is a complete list of all labels in the layer, separated by commas and followed by a dollar sign.

5. Packets of cards punched by MOSAIC, in any order. A packet starts with the forest name and ends with a dollar sign. Discard the job i.d. cards that are usually found at top and bottom of the punched deck. The forest name must match the name in Step 2, above. If packets for the same map pair appear more than once, TALLY uses the first and ignores the others.

Example of Input Deck:

```
@ RUN JACK,583301,1,30
@ CTL CLS=N, MAXCARDS=100
@ ASG X=5093
@N CUR
IN X
TRI X
```



```

@ XQT TALLY
MCCLØUD $
T41N $
PERIMETER,RL,ST,VP,WS$PERIMETER,FB,
WF2(1)*P,WF3(2),WF3(3),P4(1) $
MCCLØUD $ T41N R2W $ 11 SEP 73 $11,
1$4,5$
PERIMETER,RL,ST,VP$PERIMETER,FB,WF2(1)*P,
WF3(3),P4(1) $44,129,147,69,18,25,
7(0),73,6(0)$
MCCLØUD$ T41N R3W $ 12 SEP 73 $ 12,2$2,4$
PERIMETER,WS$PERIMETER,FB,WF3(2),P4(1)$
7,1,3(0),13,1,29 $

```

6. SUPPØRT PRØGRAMS

6.1 Plotting a Map (CHART)

CHART plots the polygons on an automatic digital plotter, allowing a map to be checked visually. The program writes pen movement instructions on a tape, and the tape runs the plotter off-line. CHART comes in two different versions: one for the Cal Comp 1136 plotter and the other for the EAI 430. We will describe the Cal Comp version first and then tell how the EAI version differs from it.

The map is drawn in two colors--the polygons in one color and their labels in another. Also plotted are the control points, the x and y scales in map coordinates, and a title, which is an extract of the header record.

Several options are available, such as plotting only a portion of the map defined by giving a list of item numbers, or blowing up the plot by including a magnification factor. And to identify the polygons there is a choice of plotting labels, label numbers, or item numbers.

(Numbering is the same as on the printout.) If a Cal Comp plotter is used, several maps can be plotted in a single run by repeating input card Sections 2 and 3 (below) for each map to be plotted. The same output tape must be used for all of them.

Input Cards:

1. System cards..

2. Header record of the map to be plotted. The forest, map number, and layer are required. Also include the input unit.

3. Control cards. A semicolon separates control cards. Punch a dollar sign at the end.

a. PLOT TAPE = tape label required). This tape will drive the plotter.

b. MAGNIFICATION = factor. This is the amount of blow-up. Omitting it is equivalent to a factor of 1.0.

c. RECTANGLE = min x, max x, min y, max y. These four numbers define a rectangle in map coordinates within which the plot is to be confined. The numbers are integers, in units of 0.01 inch. Omitting this and "ITEMS" means you want the entire map.

d. ITEMS = list of item numbers. This is another way to specify a subset of the map to be plotted.

e. PLOT ITEM NUMBERS (default)
PLOT LABELS
PLOT LABEL NUMBERS

Choose one. It tells the computer what to plot as identification on each polygon.

Example of Input Deck:

```

@ RUN SMITH,123456,2,50
@ CTL CLS=N
@ ASG A=9701
@W ASG B=8728
@ ASG X=3703
@N CUR
IN X
TRI X
@N XQT CHART
FOREST=ELDØRADØ; MAP=33; LAYER=TIMBER;
INPUT UNIT=A$
PLOT TAPE=B;
RECTANGLE=1500,2000,1700,2400;
MAGNIFICATION=2; PLOT LABELS $

```

Plotting on the EAI 430:

The ASG card for the plot tape must have the H option and there is a different program tape. In our example, the ASG cards for B and X become:

```

@WH ASG B=8728
@ ASG X=3952

```

6.2 Storing Several Maps on One Tape (FLEET)

The purpose of FLEET is to copy files (maps) from several tapes onto one tape for more compact storage. It can also be used just to copy a tape.

Copying is controlled by a sequence of header records, each containing an IO unit

name, punched on input cards. As with the other programs, only the minimum identification is required on the header cards, namely Forest, Map Number, and Layer. Any other information is for correction or expansion of the existing header record on tape. With tape input, omission of Forest, Map, and Layer inputs whatever file is next on the tape; specifying Forest, Map, and Layer causes a search through the tape until that file is found.

Example of Input Deck:

This deck copies two files from tape 1000 and one file from tape 2000, writing them onto tape 3000.

```
@ RUN MAC,583301,3,50
@ CTL CLS=N
@ ASG A=1000
@ ASG B=2000
@W ASG C=3000
@ ASG X=3950
@N CUR
IN X
TRI X
@N XQT FLEET
INPUT UNIT=A; FØREST=ELDØRADØ; MAP=10;
LAYER=TIMBER$
ØUTPUT UNIT=C$
INPUT UNIT=A; FØREST=ELDØRADØ; MAP=11;
LAYER=TIMBER$
ØUTPUT UNIT=C$
INPUT UNIT=B; FØREST=ELDØRADØ; MAP=55;
LAYER=TIMBER$
ØUTPUT UNIT=C$
```

6.3 Printing Diagnostic Summary of a Map (GØSSIP)

GØSSIP prints a detailed summary of all polygons on a map so that editing can be done and errors detected. The map to be printed and the unit it is on are identified by a header record punched on cards. Any number of maps can be printed by punching a series of header records.

When input is from tape some shortcuts are possible. As with the other programs, the file specified on cards is searched for on the tape. Therefore, any intervening unwanted files can be disregarded. But if more than one file is wanted from a tape each must be processed in order because a tape is not backed up. Another shortcut allows printing all files on a tape by punching just "INPUT UNIT = something \$."

Example. This job prints out one file from tape 7000 and all files on

tape 4000.

```
@ RUN JIM,583301,2,150
@ CTL CLS=N
@ ASG E=7000
@ ASG F=4000
@ ASG X=3951
@N CUR
IN X
TRI X
@N XQT GØSSIP
INPUT UNIT=E; FØREST=ELDØRADØ;
MAP=51; LAYER=TIMBER $
INPUT UNIT=F $
```

6.4 Printing General Summary of a Map (RUMØR)

The RUMØR program is similar to GØSSIP, but prints less detailed information about the polygons. It is intended more for the worker in the field. In practical usage, such as in keypunching, it is identical to GØSSIP in all respects except for two cards: the ASG X card, which is

```
@ ASG X=3955
```

and the XQT card, which is

```
@N XQT RUMØR
```

6.5 Housekeeping Program (SIGNAL).

If WRIS is used for a large data base, (for example, 100 maps having 1000 distinct labels), keeping track of the maps as they are processed becomes itself a considerable data handling problem. A record must be kept of what stage of processing each map is in, what tape it is on, and so forth. Each of the thousands of polygons has a label, and it must be checked against a master list of valid labels.

SIGNAL is designed to assist in these housekeeping chores. It enables the user to establish and maintain a file of information about his maps on a drum or disk unit. A "file" consists of a collection of "records," and each record contains a "key" by which it is identified. Two different kinds of files are possible, a "catalogue file" or a "master label file." In a catalogue file there is one record for each map, consisting of a portion of its header record plus a few other pieces of information. All entries in a catalogue file pertain to one forest. In a master label file there is one record for each layer in a forest, and several forests may be intermingled in one file, if desired.

Catalogue file: The permissible items in a record are: MAP, LAYER, LOCATION, DATE

OF ORIGIN, GEOGRAPHIC CONTROL POINTS, MAP CONTROL POINTS, PROJECTION, ZONE, ENVELOPE, POLYGON REEL, BACKUP REEL, GRID REEL. Most of these can be copied directly from a header record printout, using the same format. As for the others, an example is the best description:

```
DATE OF ORIGIN = 06 JAN 74;
PROJECTION = STATE PLANE;
ZONE = 13; POLYGON REEL = 9117,4;
BACKUP REEL = 5093,9; GRID REEL=7195,2$
```

In the last three items, you have the tape reel number followed by the position on the reel (assuming more than one map per reel). The retrieval key for a record in this kind of file is the map number. For keypunching rules for header records, see Section 7.3.2.

Master label file: A record is a list of all permissible labels for one forest/layer combination. The key is a string of characters composed of the forest name, a slash, and the layer name. Do not have blanks before or after the slash. When entering a list of labels, punch them on cards in the standard format for a label list (See Section 4.2)

Using SIGNAL: Acquire a Fastrand file using any name you want. Also choose a file identification, such as the forest name for a catalogue file. Twenty four characters are the maximum. Operate on a file by a series of SIGNAL control cards. The first card identifies a file by giving its Fastrand name. All further cards operate on this file until another such series is started, if any. Some control cards also refer to a tape, using its external name (A,B,C,etc.) as given on the ASG card. Some other control cards require a key, which is the map number, in the case of a catalogue file or the forest/layer, if it is a master label file. In all cases, this variable portion of a control card (file name, tape name, or key) is enclosed in parentheses. In some cases, though, this is absent and all you have is the control word itself, which is always ended with a period. Thus a control card consists of a control word or phrase specifying an action to be done on the current file, and usually the name of a file, tape, or key. For most control cards, this is enough. But for a few, some data or further control information must follow.

Control Cards: Here is a list of all possible control cards and an explanation of what they do. Lower case indicates a symbol generated by the user.

START FILE. (file name)
FILE. (file name)

Use one of these cards to name the file that subsequent control cards will operate on. This file name remains in effect until another START FILE or FILE card is encountered. The file name must be already known to the operating system. FILE assumes that a previous SIGNAL run has stored something into the file and that you are now updating it. But the first time, use START FILE to initialize. The START FILE card requires an additional control card containing two items. For a catalogue file:

ID = forest; TYPE = CATALOGUE\$

For a master label file:

ID = anything; TYPE - MASTER LABEL
FILE\$

On later runs, when the FILE card is used, the above control card is not used because the information is in the file.

CHECKPOINT OUT. (tape name)

Saves the file on tape. At a later date you can restore it by a CHECKPOINT IN. This feature is designed for file security or for simply saving rental on files. The tape name is the same as on the ASG card.

CHECKPOINT IN. (tape name)

This is the reverse of CHECKPOINT OUT. Precede this card by a START FILE card.

PRINT FILE.

Prints the file contents in full, including the index.

PACK FILE.

When the DELETE ITEM control card is used a "gap" is created in the file. If a number of such gaps are present in a file it may be economical to squeeze them out with a PACK FILE card. However, a file is automatically packed whenever it is copied onto any other medium (i.e., with CHECKPOINT OUT or COPY FILE).

COPY FILE. (file name)

This produces a copy of the file which is current (the one named on the most recent

FILE or START FILE card in the run) by writing it onto another file, the one given by "file name" on the control card.

DELETE ITEM. (key).

Deletes an item from the file, the item having the key given.

ADD ITEM. (key).

This adds an entirely new item to the file or augments an existing item, depending on whether the given key exists in the file. The new material must immediately follow the ADD ITEM card. When a catalogue file item is augmented, the new material is favored whenever there are conflicts. When a master label file is augmented, new labels in the punched list are added to the file and duplicates are ignored.

PRINT ITEM. (key)

Prints the given item in full.

PUNCH ITEM. (key)

Punches the given item.

CHECK LABELS. (key)

Used to check a given list of labels against a master list (with the key given) that is in the file. The list to be checked must immediately follow the CHECK LABELS card. And it must, as usual, end with a dollar sign. Any label in this list that does not match a label in the file is flagged in the printout, on the assumption that it is erroneous. No change is made in the file.

DELETE LABELS. (key)

With this control card you can delete any of the labels in a master label list (the given key tells which list). Punch the labels to be deleted in label list format and put them after the DELETE LABELS card.

SO RT LABELS. (key)

Sorts a master label list (denoted by key) into alphabetical order and writes it back into the file, replacing the old list.

Deck setup

This job establishes a file for master

labels, stores a label list in it, sorts it, and prints it.

```
@ RUN FRED,583301,1,20
@ CTL CLS=N
@ ASG X=5103
@N CUR
IN X
TRI X
@N XQT FMAPS
AQR BIG/F00T,1
@N XQT SIGNAL
START FILE. (BIG/F00T)
ID=SIERRA; TYPE=MASTER LABEL FILE $
ADD ITEM. (SIERRA/TIMBER)
PP,D,W,F,W,SP$
SO RT ITEM. (SIERRA/TIMBER)
PRINT ITEM. (SIERRA/TIMBER)
```

7. PROGRAM NOTES

Miscellaneous information that applies to more than one of the programs is located in this section.

7.1 Computer System

The computer we use is a Univac 1108 computer (Exec 2 operating system). The scanner is a PDS microdensitometer, and the plotter can be either a Cal Comp 1136 or an EAI 430. The programs are written in Fortran and are very close to the ANSI standard.

7.2 Files

The data processed by the WRIS programs is kept permanently on magnetic tapes or on Fastrand drums. These two media are interchangeable to the programs. For simplicity and to correspond to present practice, we usually refer to a file as being on tape. A "file" in this context is essentially one map. However, several files can be stored on one tape, but only one on Fastrand.

The tape or Fastrand Unit onto which a file is to be written has a name. It is a letter (A, B, C,...) for tapes and two 1-6 character names separated by a slash for Fastrand. Each program requires this unit name to be punched on cards, usually included in the header record. Sometimes you may want to specify no unit, perhaps to indicate that no output file is to be written. In this case use the word "NONE" as unit name. Some examples should illustrate these rules. "INPUT UNIT=A" included in the header record specifying an input file says it is on the tape unit assigned to "A" on the ASG card. If it were an output file you would punch "OUTPUT UNIT=A."

Or, "ØOUTPUT UNIT=NONE" is possible.

Files have a MODE attribute appearing in header records. It is automatically generated by the computer. MODE=1 indicates a map in scanner (grid) form. MODE=2 indicates a map consisting of a collection of non-overlapping polygons.

7.3 Card Formats

Certain forms recur in the card input to the various WRIS programs. Header records and polygon labels are examples previously described. Others are described in the following sections. Card input to a program is of two kinds: system cards and program input cards.

7.3.1 System Cards

Rules for these cards are determined by the computer installation and are thus out of the programmer's control. These few cards are at the beginning of a job deck. On the Univac 1108, Exec 2, an "a" character in column 1 identifies most of them. They consist of all cards up to and including the card with "XQT" on it.

In each program writeup, an example shows what should be punched. Observe the placement of spaces carefully. Most of the cards are the same for each run. Mainly what varies are (a) the time and page estimates on the RUN card, and (b) the unit assignments and tape reel numbers on the ASG cards, other than the one naming the program file.

7.3.2 Header Records

Items: A header record is a small collection of information about one map file. This information pertains to the entire map, rather than to specific polygons. Part of it identifies the map. Most programs in WRIS require these identifiers in order to use an existing file. The others are generated and maintained internally. Each time a file is processed, its current header record is printed in full. The user can override an internally generated value, but not the three basic identifiers--FOREST, MAP, LAYER. To override one of the others, punch the desired value along with the required identifiers. The header record is stored on tape along with the file at all times.

Here is a complete list of possible items in a header record. Capital letters give the "official" names, in the only

spelling recognized by WRIS (and only one blank between words please).

FOREST: The name of the forest. (characters)

MAP: Map number. (integer)

LAYER: Layer name. (characters)

LOCATION: Location. (characters)

SCALE: Representative fraction denominator, defined as the number of inches on the ground represented by one inch on the map. A 4-inch-per-mile map has, for example, a representative fraction of 1/15840. (integer)

GEOGRAPHIC CONTROL POINTS: Latitude and longitude of each control point, latitude preceding longitude for each point. Use degrees, minutes and seconds, separated by colons. Do not omit zeroes. In the seconds position, you can record to the nearest hundredth second using a decimal point. An accuracy of at least 0.5 second is essential. The maximum meaningful accuracy is 0.01 second.

MAP CONTROL POINTS: x and y coordinates of the control points, in units of 0.01 inch on the map. (integers)

GRID CONTROL POINTS: Row and column coordinates of the control points. (integers)

SCAN ROWS: Number of rows scanned. (integer)

SCAN COLUMNS: Number of columns scanned. (integer)

MODE: Indicates a scan grid (MODE=1) or a polygon map (MODE=2). (integer)

ENVELOPE: Overall envelope of all polygons on the map, i.e., the smallest x, smallest y, largest x, and largest y. Same units as map control points. (integers).

DATE WRITTEN: The date the file was written. (characters)

TIME WRITTEN: The time the file was written. (characters)

REEL NUMBER: Tells which tape reel the file is on. (characters)

POSITION ON REEL: Indicates one of perhaps several files on the reel. (integer)

Control points: Township corners are usually selected as control points, although any other sharply defined locations will do. These are recorded in a clockwise manner starting in the lower left corner. Four corners are the most desirable but three (or even two) may be sufficient. The corner must be a recognizable point on or within the map boundary, not some arbitrary point on the map sheet. Control points must be identical for all layers of a township as well for all systems of measurement; in other words, they represent the same ground locations on all layers, and are recorded in the same order.

Format of a header record: A free-field format is used. Items do not have to appear in specified card columns. The computer knows what each item is because it is labeled; for example, "MAP=51" means 51 is the map number. The equals sign attaches the name "MAP" to the value 51. The computer program has a list of these names; therefore, names must be spelled correctly. Sometimes a name requires more than one number as its value. Punch commas between the numbers to separate them. Sometimes a value is not a number but a string of characters. In "FØREST=ELDØRADØ" the value is "ELDØRADØ."

Thus, we have the basic building block of a header record, namely an item of the form name=value, where the name on the left is from a standard list of names and the value on the right can be a number, several numbers separated by commas, or a string of characters. It is all right to put in extra spaces (blank columns) just so they aren't in the middle of a number or word. Thus, "MAP = 51" and "MAP=51" are both permissible. But blanks in a string value are significant. "ELDORADO" is not the same as "EL DORADO." In key punching, when you reach column 80, continue directly to column 1 of the next card, as if you had one long continuous card.

To form a complete header record, punch one item after another, separated by semicolons, and punch a dollar sign at the end to signal the end of the header record. Again, blanks may be freely inserted before and after these punctuation characters. Here is an example of a complete header record:

```
FØREST=ELDØRADØ; MAP=51;
LØCATIØN=T14N R15E; LAYER=TIMBER$
```

7.3.3 Integer Lists

Many programs will require a list of integers (whole numbers without decimal points) as input from cards at some point, and some header record items are in this form. Rather than require a fixed field size and card location for each number, we use a free format. The integers are punched in as many columns as are needed. Successive integers are separated by commas. The list is terminated by either a semi-colon or a dollar sign, depending on context. When you reach column 80, continue on to the next card as if it were one long card. Blanks (skipped columns) can be inserted anywhere except between the digits of a number.

Three abbreviations are possible: (a) A sequence of increasing or decreasing numbers such as "6, 7, 8, 9" can be shortened to "6Δ9". (b) A repetition of the same number, such as "4,4,4,4,4" can be abbreviated "5(4)". A combination is possible, such as "2(5,7Δ9)", which is the same as "5,7,8,9,5,7,8,9". In other words, whatever is inside the parentheses is repeated as many times as the number in front indicates. (c) For ease in recording sequences of coordinate pairs, we allow the special forms [x,aΔb] and [aΔb,y]. The letters stand for integers. For example, "[31,617Δ653]" is the same as "31,617,31,618,...,31,653".

7.3.4 Comments

Comments can be included anywhere in the program input cards by enclosing the comment material in quote marks. A comment is a note to yourself that you do not want the computer to read. Whenever the computer comes to a quote mark in the input stream, it scans forward until the matching quote mark is found and resumes processing at that point.

7.4 Printout

Some items show up on nearly every printout and may need some explanation. First, every card in the input deck is printed. Those after the XQT card are labelled "INPUT CARD:" This helps you check your work in case an error develops. Every page printed by the program itself (i.e., after XQT) is headed by the program name, the date, and a page number. The date and time of day is printed at beginning and end of the program printout. The message "END OF RUN" is printed at the end. Most of the input information

is printed back at you in a somewhat different form than what was punched on the cards, showing you what the computer thinks it is. This helps you spot errors. Whenever there is an output file, the message "ØUTPUT FILE WRITTEN" will be printed after the writing is complete. You need this message to be sure the file can be read as input in a future run.

8. APPENDIXES

A--Rules for Transcribing Forest Type Descriptions to Computer-readable Format

Reference: Region 5, U.S. Forest Service, Section 2441 (2441.1 - 2441.5) Forest Types and Classification System

Encoding Rules:

1. Species symbols (capital letters) are copied unchanged. Species symbols which are lower case letters are discussed later, in item 4.
2. u, s, and o become capitals; i.e., U, S, and Ø.
3. Numerals do not change.
4. The asterisk (*) marks the beginning of lower case species letters. If there is no lower case then there is no asterisk.
5. The dash (-) separates two species. It is not needed between a species in upper case and one in lower case because the asterisk serves the same purpose in this instance.
6. (1) replaces - , (2) replaces = , (3) replaces ≡ ,
7. Each label is followed by its x and y coordinates (in hundredths of an inch, as integers) by using one or more blanks as separators between them. Then, if another

label follows, insert a comma. If not, use a dollar sign to signal the end of the list of labels.

Keypunch Symbol	Function
/	Replaces the "fraction bar"
*	Precedes lower case letters
-	Separates species
(3)	Replaces ≡ . The numeral is the number of dashes.
+	Replaces colon (:)
UB	Replaces U-Br
WA	Replaces W (water)
B	Replaces Br (brush)
NØ	Indicates NØ LABEL
XF	Experimental Forest
XX	Private land inside N.F.
XY	Any land ownership outside N.F.
RL	Reserved land (wilderness)

Examples:

Map Symbol	Characters recorded on data form for keypunching
SPwfrf5= WFrfs=	SP*WF-RF5(2)/WF*RF3(3)
SPwfrf5(s) WFrfs(o)	SP*WF-RF5(S)/WF*RF3(Ø)
PL:P1(u)	PL+P1(U)
U	U
U-Br	UB
SP5= wfrf3=	SP5(2)/*WF-RF3(3)
WFpsp5- WFsp4= WF3=	WF*P-SP5(1)/WF*SP4(2)/WF3(2)
BA	BA
NC	NC

B--Major Forest Type Assignments

MAJOR FOREST TYPE -----	VEGETATIVE TYPE -----
A	A
B	B
BA	BA
G	G
HD	HD
NC	NC
NO	NO
PL	PL+P*SP1(S), PL+P1(O), PL+P1(S), PL+P1(U), PL+P2(S), PL+P2(2), PL+P2(3), PL+P2(4), PL+RW1(S), PL+SP*P1(S), PL+SP1(U)
RL	RL
U	U
WA	WA
XX	XX
XY	XY
D.1	D*P5(2)/D*IC3(2), D*P5(2)/D2(2), D*SP5(2), D*SP5(2)/D*IC2(2), D*SP5(2)/D*SP2(2), D*SP5(2)/D*SP3(2), D*SP5(2)/D2(2), D*SP5(2)/D3(2), D*SP5(2)/D4(1)/D*P3(2), D*SP5(2)/D4(1)/D3(2), D*SP5(3), D5(1)/D4(1)/D2(2), D5(1)/D4(1)/D3(2), D5(1)/P4(1)/D*P2(2), D5(2), D5(2)/D2(2), D5(2)/D3(1), D5(2)/D3(2), D5(2)/D4(1)/D*IC3(2), D5(3), D5(3)/D2(2)
D.2	D*IC3(2), D*IC4(2), D*P2(2), D*P3(2), D*P4(2), D*SP3(2), D*SP4(2), D2(1), D2(2), D3(1), D3(2), D4(1), D4(1)/D*SP3(2), D4(2), D5(1), D5(1)/P3(1)
D.3A	D*P-SP4(4), D*SP4(4), D4(4), D5(1)/D*IC3(2), D5(1)/D3(2), D5(1)/IC*D3(2)
D.3B	D*IC4(3), D*P-IC4(3), D*P-SP4(3), D*P4(2)/D*IC2(2), D*P4(2)/D2(2), D*P4(2)/IC*D2(2), D*P4(2)/IC2(2), D*P4(2)/P*D2(2), D*P4(2)/P*IC2(2), D*P4(3), D*SP-P4(3), D*SP4(2)/D*IC2(2), D*SP4(2)/D*SP2(2), D*SP4(2)/D2(2), D*SP4(3), D4(1)/D*IC2(2), D4(1)/D*P2(2), D4(1)/D*SP2(2), D4(1)/D2(2), D4(1)/P*D2(2), D4(2)/D*IC2(2), D4(2)/D2(2), D4(3), D5(1)/D*IC2(2)
D.4A	D5(1)/D*IC4(2)/D2(2), D5(1)/D*P4(2)/D*IC2(2), D5(1)/D*P4(2)/D3(2), D5(1)/D*SP4(2)/D*IC2(2), D5(1)/D*SP4(2)/D2(2), D5(1)/D*SP4(2)/D3(1), D5(1)/D*SP4(2)/D3(2), D5(1)/D4(2)/D2(2), D5(1)/D4(2)/D3(2)
D.4B	D*IC5(2)/D*IC3(3), D*P4(2)/D*IC2(3), D*P4(2)/D*SP2(3), D*P4(2)/D2(3), D*P5(2)/D3(3), D*SP4(2)/D*IC2(3), D*SP4(2)/D*SP2(3), D*SP4(2)/D2(3), D*SP5(2)/D*IC3(3), D*SP5(2)/D*SP3(3), D*SP5(2)/D2(3), D*SP5(2)/D3(3), D4(1)/D*IC2(3), D4(1)/D*P2(3), D4(1)/D2(3), D4(1)/IC*SP2(3), D4(1)/P*D2(3), D4(2)/D*IC2(3), D4(2)/D2(3), D5(1)/D*IC2(3),

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	D5(1)/D*IC3(3), D5(1)/D*P3(2)/D2(2), D5(1)/D*P3(3), D5(1)/D*SP3(3), D5(1)/D2(3), D5(1)/D3(1)/D*P2(2), D5(1)/D3(2)/D2(2), D5(1)/D3(3), D5(2)/D3(3)
D.5A	D*P4(2)/D*IC3(2), D4(2)/D*IC3(2)
D.5B	D*IC3(3), D*P-IC3(3), D*P-SP3(3), D*P3(3), D*P3(4), D*P3(5)
D.6	D*P-IC2(3), D*P2(3), D*P2(4)
KP.6	KP2(3), KP2(4)
MC.1	D*SP-WF5(3), D*SP5(2)/D*WF3(2), D*SP5(2)/P4(1)/D*WF3(2), D*WF-SP5(3), D*WF5(2), D*WF5(2)/D*IC3(2), D*WF5(2)/D*P2(2), D*WF5(2)/D*WF3(2), D*WF5(2)/D3(2), D*WF5(2)/P4(1)/D*WF3(2), D*WF5(2)/D4(1)/D*WF3(2), D*WF5(2)/WF4(1)/D*WF3(2), D*WF5(3), D5(1)/D4(1)/D*WF3(2), D5(1)/P4(1)/D*WF3(2), D5(2)/D*WF3(2), D5(2)/D*WF3(2), P*D-SP5(3), P*D5(2)/D*WF3(2), P*D5(2)/D*WF3(2), P*D5(2)/D*WF3(2), P*D5(2)/D3(2), P*RF5(2), P*RF5(2)/D*WF3(2), P*RF5(2)/RF*WF3(2), P*RF5(2)/RF3(2), P*RF5(2)/WF3(2), P*RF5(2)/WF3(2), P*RF5(3), P*SP-RF5(3), P*SP-WF5(3), P*SP5(2), P*SP5(2)/D*IC3(2), P*SP5(2)/D*WF3(2), P*SP5(2)/D2(2), P*SP5(2)/P*IC3(2), P*SP5(2)/P*P3(2), P*SP5(2)/P*WF2(2), P*SP5(2)/P*WF3(2), P*SP5(2)/P2(2), P*SP5(2)/P3(2), P*SP5(2)/P4(1)/D*WF3(2), P*SP5(2)/P4(1)/D*P3(2), P*SP5(2)/P4(1)/WF*P3(2), P*SP5(2)/RF*WF3(2), P*SP5(2)/RF3(2), P*SP5(2)/WF*IC3(2), P*SP5(2)/WF*P3(2), P*SP5(2)/WF*RF2(2), P*SP5(2)/WF*RF3(2), P*SP5(2)/WF3(2), P*SP5(3), P*WF-RF5(3), P*WF-SP5(3), P*WF5(2), P*WF5(2)/P*WF3(2), P*WF5(2)/P3(1)/P*WF2(2), P*WF5(2)/RF*WF3(2), P*WF5(2)/RF*WF3(2), P*WF5(2)/RF2(2), P*WF5(2)/WF*P3(2), P*WF5(2)/WF*IC3(2), P*WF5(2)/WF*P2(2), P*WF5(2)/WF*P3(2), P*WF5(2)/WF2(2), P*WF5(2)/WF3(2), P*WF5(3), P5(1)/D4(1)/D*WF2(2), P5(1)/D4(1)/WF*D2(2), P5(1)/P4(1)/D*WF3(2), P5(1)/P4(1)/P*WF2(2), P5(1)/P4(1)/P*WF3(2), P5(1)/P4(1)/WF*D2(2), P5(1)/P4(1)/WF*D3(2), P5(1)/P4(1)/WF*P2(2), P5(1)/P4(1)/WF*P3(2), P5(1)/P4(1)/WF*RF2(2), P5(1)/P4(1)/WF*RF3(2), P5(1)/RF4(1)/RF*WF2(2), P5(1)/WF4(1)/P*WF2(2), P5(1)/WF4(1)/WF*D3(2), P5(1)/WF4(1)/WF*P3(2), P5(1)/WF4(1)/WF2(2), P5(1)/WF4(1)/WF3(2), P5(2)/P*WF3(2), P5(2)/WF4(1)/WF3(2), SP*D5(2)/D*WF3(2), SP*D5(2)/D2(2), SP*P5(3), SP*P5(2)/P*WF2(2), SP*P5(2)/P4(1)/WF*P3(2), SP*P5(2)/RF*SP2(2), SP*P5(2)/WF*IC3(2), SP*P5(2)/WF3(2), SP*RF5(3), SP5(1)/P4(1)/P3(2), SP5(1)/P4(1)/WF*P3(2), SP5(1)/P4(1)/WF*RF3(2), SP5(1)/SP4(1)/WF*RF3(2), SP5(1)/WF4(1)/WF*D3(2), SP5(1)/WF4(1)/WF*RF3(2), SP5(1)/WF4(1)/WF3(2), WF*D-IC5(3), WF*D-SP5(3), WF*D-SP5(4), WF*D5(2), WF*D5(2)/D*WF2(2), WF*D5(2)/D*WF3(2), WF*D5(2)/WF*D3(2), WF*D5(3), WF*P-D5(3), WF*P-RF5(3), WF*P-SP5(3), WF*P4(2)/P4(2)/WF3(2), WF*P5(2), WF*P5(2)/WF3(2), WF*P5(3), WF*RF-P5(3), WF*RF-SP5(3), WF*RF5(2), WF*RF5(2)/RF*LP3(2), WF*RF5(2)/WF4(1)/WF*RF3(2), WF*RF5(3), WF*SP-P5(3), WF*SP5(2)/WF*P2(2), WF*SP5(2)/WF3(2), WF*SP5(3), WF4(1)/WF4(1)/WF3(1), WF5(1)/WF4(1)/D*WF3(2), WF5(1)/WF4(1)/WF3(2), WF5(2)/WF*P3(2)
MC.2	D*WF2(2), D*WF3(2), D*WF4(2), D5(1)/WF4(1), IC*WF2(2), LP*WF3(2), P*D2(2), P*D3(2), P*D4(2), P*LP3(2), P*LP4(2), P*RF2(2), P*RF3(2), P*RF4(2), P*SP3(2), P*SP4(2), P*WF2(2), P*WF3(2), P*WF4(2), SP*D4(2), SP*P3(2), SP*P4(2), SP*RF4(2), SP*WF4(2), SP3(1), SP3(2), SP4(1), SP4(2), SP5(1), WF*D2(2), WF*D3(2)

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WF*D4(2), WF*IC3(2), WF*LP4(2), WF*P2(2), WF*P3(2), WF*P4(2),
WF*RF2(2), WF*RF3(2), WF*RF4(2), WF*SP2(2), WF*SP3(2), WF*SP4(2),
WF2(1), WF2(2), WF3(1), WF3(2), WF4(1), WF4(2), WF5(1)

MC.3A

D*P-WF4(4), D*WF-IC4(4), D*WF-P4(4), D*WF-SP4(4), D*WF4(4),
D5(1)/D*WF-SP4(3), D5(1)/D*WF3(2), P*D-IC4(3)/P2(2),
P*D-SP4(3)/D*SP2(2), P*D-SP4(4), P*D4(4), P*RF4(4), P*WF-D4(4),
P*WF-SP4(4), P5(1)/D*WF3(2), P5(1)/P*WF3(2), P5(1)/RF*WF3(2),
P5(1)/RF4(3)/WF*RF2(2), P5(1)/WF*D3(2), P5(1)/WF*IC3(2),
P5(1)/WF*LP3(2), P5(1)/WF*P3(2), P5(1)/WF*P4(3), P5(1)/WF*RF3(2),
P5(1)/WF3(2), P5(1)/WF4(2), SP5(1)/D3(2), SP5(1)/RF*SP3(2),
SP5(1)/RF*WF3(2), SP5(1)/WF*P3(2), SP5(1)/WF*RF3(2),
SP5(1)/WF*SP3(2), SP5(1)/WF3(2), WF*D-P4(4), WF*D-SP4(4),
WF*D4(3)/D2(2), WF*D4(4), WF*P-SP4(4), WF*P4(4), WF*RF-SP4(4),
WF*RF4(4), WF*SP-IC4(4), WF4(4), WF5(1)/D*WF3(2),
WF5(1)/IC*WF3(2), WF5(1)/WF*P3(2), WF5(1)/WF*RF3(2),
WF5(1)/WF3(2), WF5(1)/WF4(2)

MC.3B

D*IC-WF4(3), D*P-WF4(3), D*P4(2)/D*WF2(2), D*P4(2)/IC*WF2(2),
D*SP-WF4(3), D*SP4(2)/D*WF2(2), D*WF-IC4(3), D*WF-P4(3),
D*WF-SP4(3), D*WF4(2)/D*WF2(2), D*WF4(2)/D2(2),
D*WF4(2)/IC*D2(2), D*WF4(3), D4(1)/D*WF2(2), D5(1)/WF*D2(2),
LP*P-WF4(3), LP*RF-WF4(3), P*D-IC4(3), P*D-SP4(3), P*D-WF4(3),
P*D4(2)/D*IC2(2), P*D4(2)/D*P2(2), P*D4(2)/D2(2),
P*D4(2)/IC*D2(2), P*D4(2)/IC*P2(2), P*D4(2)/P*D2(2),
P*D4(2)/P*IC2(2), P*D4(2)/P*WF2(2), P*D4(2)/WF*P2(2), P*D4(3),
P*IC-WF4(3), P*IC4(2)/P*WF2(2), P*RF-WF4(3), P*RF4(2)/RF*P2(2),
P*RF4(2)/RF2(2), P*RF4(2)/WF*RF2(2), P*RF4(3), P*SP-D4(3),
P*SP-IC4(3), P*SP-RF4(3), P*SP-WF4(3), P*SP4(2)/D*WF2(2),
P*SP4(2)/D2(2), P*SP4(2)/IC*P2(2), P*SP4(2)/P*D2(2),
P*SP4(2)/P*IC2(2), P*SP4(2)/P*SP2(2), P*SP4(2)/P*WF2(2),
P*SP4(2)/P2(2), P*SP4(2)/WF*D2(2), P*SP4(2)/WF*IC2(2),
P*SP4(2)/WF*P2(2), P*SP4(2)/WF*RF2(2), P*SP4(2)/WF2(1),
P*SP4(2)/WF2(2), P*SP4(3), P*WF-D4(3), P*WF-IC4(3), P*WF-RF4(3),
P*WF-SP4(3), P*WF4(2)/D*P2(2), P*WF4(2)/D*WF2(2),
P*WF4(2)/IC*P2(2), P*WF4(2)/IC*WF2(2), P*WF4(2)/P*D2(2),
P*WF4(2)/P*IC2(2), P*WF4(2)/P*WF2(2), P*WF4(2)/P2(2),
P*WF4(2)/WF*D2(2), P*WF4(2)/WF*IC2(2), P*WF4(2)/WF*P2(2),
P*WF4(2)/WF*RF2(2), P*WF4(2)/WF2(2), P*WF4(3), P4(1)/D*WF2(2),
P4(1)/P*WF2(2), P4(1)/WF*IC2(2), P4(1)/WF*P2(2), P4(1)/WF*RF2(2),
P4(1)/WF2(2), P4(2)/P*WF2(2), P5(1)/D*WF2(2), P5(1)/P*WF2(2),
P5(1)/WF*D2(2), P5(1)/WF*IC2(2), P5(1)/WF*P2(2), P5(1)/WF*RF2(2),
P5(1)/WF2(2), SP*P4(2)/P*WF2(2), SP*P4(2)/SP*D2(2),
SP*P4(2)/SP*IC2(2), SP*P4(2)/WF2(2), SP*P4(3), SP*RF-WF4(3),
SP*WF4(3), SP4(2)/SP*P2(2), SP4(2)/WF2(2), SP5(1)/SP*IC2(2),
SP5(1)/WF*D2(2), WF*D-IC4(3), WF*D-P4(3), WF*D-RF4(3),
WF*D-SP4(3), WF*D4(2)/D*WF2(2), WF*D4(2)/D2(2),
WF*D4(2)/IC*P2(2), WF*D4(2)/WF*D2(2), WF*D4(3), WF*IC-P4(3),
WF*IC4(2)/WF*IC2(2), WF*IC4(3), WF*LP4(3), WF*P-D4(3),
WF*P-IC4(3), WF*P-RF4(3), WF*P-SP4(3), WF*P4(2)/IC*WF2(2),
WF*P4(2)/LP2(2), WF*P4(2)/P*IC2(2), WF*P4(2)/P*SP2(2),
WF*P4(2)/WF*D2(2), WF*P4(2)/WF*IC2(2), WF*P4(2)/WF*P2(2),
WF*P4(2)/WF2(2), WF*P4(3), WF*RF-D4(3), WF*RF-LP4(3),
WF*RF-P4(3), WF*RF-SP4(3), WF*RF4(2)/WF*LP2(2),
WF*RF4(2)/WF*RF2(2), WF*RF4(2)/WF2(2), WF*RF4(3), WF*SP-D4(3),
WF*SP-IC4(3), WF*SP-P4(3), WF*SP-RF4(3), WF*SP4(2)/WF*IC2(2),
WF*SP4(2)/WF*P2(2), WF*SP4(2)/WF2(2), WF*SP4(3), WF4(1)/D*WF2(2),
WF4(1)/P*WF2(2), WF4(1)/RF*WF2(2), WF4(1)/WF*IC2(2),
WF4(1)/WF*P2(2), WF4(1)/WF*RF2(2), WF4(1)/WF2(2), WF4(2)/WF2(2),
WF4(3), WF5(1)/P*IC2(2), WF5(1)/WF2(2)

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D**P5(2)/D**WF4(2)/IC2(1), D**SP5(2)/D**WF-SP4(3),
D**WF5(2)/D**WF-SP4(3), D**WF5(2)/D**WF4(2)/D**WF2(2),
D**WF5(2)/D**WF4(2)/D2(1), D**WF5(2)/D**WF4(2)/D3(1),
D5(1)/D**P4(2)/D**WF3(2), D5(1)/D**SP4(2)/D**WF3(2),
D5(1)/D**WF4(2)/D**SP3(2), D5(1)/D**WF4(2)/D**WF2(2),
D5(1)/D**WF4(2)/D**WF3(2), D5(1)/D**WF4(2)/D2(2),
D5(1)/D**WF4(2)/D3(2), D5(1)/D**WF4(2)/WF**D3(2),
D5(1)/D**WF4(2)/WF**SP3(2), D5(1)/D**WF4(2)/WF3(1),
D5(1)/D**WF4(2)/WF3(2), D5(1)/WF**D4(2)/D2(2),
D5(1)/WF**D4(2)/WF**D3(2), D5(1)/WF4(2)/WF**D2(2),
P**SP5(2)/P**WF4(2)/WF**P3(2), P**SP5(2)/P4(2)/P**WF2(2),
P5(1)/D**P4(2)/D**WF3(2), P5(1)/D**WF4(2)/D**WF3(2),
P5(1)/D**WF4(2)/WF**D3(2), P5(1)/P**IC4(2)/P**WF3(2),
P5(1)/P**SP4(2)/P**WF3(2), P5(1)/P**SP4(2)/WF**P3(2),
P5(1)/P**SP4(2)/WF3(2), P5(1)/P**WF4(2)/D**WF2(2),
P5(1)/P**WF4(2)/LP3(2), P5(1)/P**WF4(2)/P**IC2(2),
P5(1)/P**WF4(2)/P**WF2(2), P5(1)/P**WF4(2)/P**WF3(2),
P5(1)/P**WF4(2)/WF**P2(2), P5(1)/P**WF4(2)/WF**P3(2),
P5(1)/P**WF4(2)/WF**RF2(2), P5(1)/P**WF4(2)/WF**RF3(2),
P5(1)/P**WF4(2)/WF2(2), P5(1)/P**WF4(2)/WF3(2),
P5(1)/P4(2)/P**WF2(2), P5(1)/P4(2)/P**WF3(2),
P5(1)/RF**WF4(2)/RF3(2), P5(1)/RF**WF4(2)/WF3(2),
P5(1)/WF**D4(2)/D**WF3(2), P5(1)/WF**D4(2)/WF**D3(2),
P5(1)/WF**D4(2)/WF3(2), P5(1)/WF**P4(2)/WF**IC2(2),
P5(1)/WF**P4(2)/WF**IC3(2), P5(1)/WF**P4(2)/WF2(2),
P5(1)/WF**P4(2)/WF3(2), P5(1)/WF**RF4(2)/RF**WF2(2),
P5(1)/WF**RF4(2)/WF**RF3(2), P5(1)/WF**SP4(2)/WF**D2(2),
P5(1)/WF**SP4(2)/WF**SP3(2), P5(1)/WF**SP4(2)/WF3(2),
P5(1)/WF4(2)/P**IC3(2), P5(1)/WF4(2)/WF**IC2(2),
P5(1)/WF4(2)/WF**LP3(2), P5(1)/WF4(2)/WF2(2), P5(1)/WF4(2)/WF3(2),
P5(2)/WF**RF4(2)/LP3(2), SP**D5(2)/D**SP4(2)/D3(1),
SP5(1)/D**WF4(2)/WF**D3(2), SP5(1)/P**WF4(2)/WF**P2(2),
SP5(1)/P**WF4(2)/WF**RF3(2), SP5(1)/SP**WF4(2)/WF**P3(2),
SP5(1)/SP**WF4(2)/WF3(2), SP5(1)/WF**P4(2)/WF2(2),
SP5(1)/WF**RF4(2)/RF**WF3(2), SP5(1)/WF**SP4(2)/WF**P3(2),
SP5(1)/WF**SP4(2)/WF**SP3(2), SP5(1)/WF**SP4(2)/WF3(2),
SP5(1)/WF4(2)/WF**D3(2), SP5(1)/WF4(2)/WF3(2),
WF5(1)/WF**D4(2)/WF**D2(2), WF5(1)/WF**D4(2)/WF**D3(2),
WF5(1)/WF**SP4(2)/WF**P3(2), WF5(1)/WF**SP4(2)/WF3(2),
WF5(1)/WF4(2)/WF2(2), WF5(1)/WF4(2)/WF3(2)

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D**P4(2)/WF**D2(3), D**P5(2)/D**WF3(3), D**SP4(2)/D**WF2(3),
D**SP5(2)/D**WF-SP3(3), D**SP5(2)/D**WF3(3), D**WF4(2)/D**IC2(3),
D**WF4(2)/D**WF-IC2(3), D**WF4(2)/D**WF2(3), D**WF4(2)/D2(3),
D**WF4(2)/WF**D-IC2(3), D**WF4(2)/WF**D2(3), D**WF5(2)/D**WF2(3),
D**WF5(2)/D**WF3(3), D**WF5(2)/D3(3), D**WF5(2)/WF**D3(3),
D4(1)/D**WF-SP2(3), D4(1)/D**WF2(3), D5(1)/D**WF-IC3(3),
D5(1)/D**WF-P3(3), D5(1)/D**WF-SP3(3), D5(1)/D**WF3(3),
D5(1)/D4(1)/D**WF3(3), D5(1)/WF**D3(3), D5(1)/WF3(3),
D5(1)/WF4(1)/D**WF3(3), P**D4(2)/D**IC2(3), P**D4(2)/D**P2(3),
P**D4(2)/D2(3), P**D4(2)/P**WF-IC2(3), P**D5(2)/D**IC3(3),
P**D5(2)/D**WF3(3), P**IC5(2)/WF3(3), P**RF4(2)/P**WF-RF2(3),
P**RF5(2)/RF**LP3(3), P**RF5(2)/RF3(3), P**RF5(2)/WF**RF2(3),
P**RF5(2)/WF**RF3(3), P**SP4(2)/D**P-SP2(3), P**SP4(2)/D**SP2(3),
P**SP4(2)/D2(3), P**SP4(2)/P**WF-IC2(3), P**SP4(2)/WF**IC2(3),
P**SP4(2)/WF**P2(3), P**SP5(2)/D**IC3(3), P**SP5(2)/D**WF2(3),
P**SP5(2)/D2(3), P**SP5(2)/D3(3), P**SP5(2)/P**SP-WF3(3),
P**SP5(2)/P**SP3(3), P**SP5(2)/P**WF-IC3(3), P**SP5(2)/P**WF-SP3(3),
P**SP5(2)/P**WF2(3), P**SP5(2)/P**WF3(3), P**SP5(2)/RF**P3(3),
P**SP5(2)/RF**WF3(3), P**SP5(2)/RF3(3), P**SP5(2)/WF**D-P3(3),
P**SP5(2)/WF**D3(3), P**SP5(2)/WF**IC3(3), P**SP5(2)/WF**P3(3),

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P*SP5(2)/WF*RF-P2(3), P*SP5(2)/WF*SP3(3), P*SP5(2)/WF3(3),
P*WF4(2)/D*WF2(3), P*WF4(2)/D2(3), P*WF4(2)/P*IC2(3),
P*WF4(2)/WF*D2(3), P*WF4(2)/WF*IC2(3), P*WF4(2)/WF*P-IC2(3),
P*WF4(2)/WF2(3), P*WF5(2)/P*WF3(3), P*WF5(2)/WF*IC2(3),
P*WF5(2)/WF*IC3(3), P*WF5(2)/WF*P3(3), P*WF5(2)/WF*RF3(3),
P*WF5(2)/WF3(3), P4(1)/D*WF-P2(3), P4(1)/D*WF2(3),
P4(1)/P*SP-WF2(3), P4(1)/P*WF-D2(3), P4(1)/P*WF-IC2(3),
P4(1)/P*WF2(3), P4(1)/WF*IC2(3), P4(1)/WF*P-IC2(3),
P4(1)/WF*RF-P2(3), P4(2)/P*WF2(3), P4(2)/RF*WF2(3),
P4(2)/WF*P2(3), P5(1)/D*WF-P3(3), P5(1)/D*WF3(3),
P5(1)/LP*WF3(3), P5(1)/P*D-WF3(3), P5(1)/P*IC3(2)/P*WF2(2),
P5(1)/P*LP-WF3(3), P5(1)/P*RF-WF3(3), P5(1)/P*SP-WF3(3),
P5(1)/P*SP-WF3(4), P5(1)/P*WF-D3(3), P5(1)/P*WF-IC2(3),
P5(1)/P*WF-IC3(3), P5(1)/P*WF-IC3(4), P5(1)/P*WF-LP3(3),
P5(1)/P*WF-RF3(3), P5(1)/P*WF-SP3(3), P5(1)/P*WF-SP3(4),
P5(1)/P*WF2(3), P5(1)/P*WF3(2)/P*WF2(2), P5(1)/P*WF3(2)/WF*P2(2),
P5(1)/P*WF3(3), P5(1)/P*WF3(4), P5(1)/P3(1)/P*WF-IC2(3),
P5(1)/P3(1)/P*WF2(2), P5(1)/P3(2)/WF2(2), P5(1)/P4(1)/D*WF-P3(3),
P5(1)/P4(1)/D*WF3(3), P5(1)/P4(1)/P*WF-IC2(3),
P5(1)/P4(1)/P*WF-IC3(3), P5(1)/P4(1)/P*WF-RF3(3),
P5(1)/P4(1)/P*WF-SP3(3), P5(1)/P4(1)/P*WF3(3),
P5(1)/P4(1)/WF*D3(3), P5(1)/P4(1)/WF*P3(3),
P5(1)/P4(1)/WF*RF-P3(3), P5(1)/P4(1)/WF*RF3(3),
P5(1)/RF*P-WF3(3), P5(1)/RF*WF-LP3(3), P5(1)/RF*WF3(2)/RF2(2),
P5(1)/RF*WF3(3), P5(1)/WF*D-IC3(3), P5(1)/WF*D-P3(4),
P5(1)/WF*D3(3), P5(1)/WF*IC-P2(3), P5(1)/WF*IC3(3),
P5(1)/WF*LP3(3), P5(1)/WF*P-IC3(3), P5(1)/WF*P-RF3(3),
P5(1)/WF*P-SP3(3), P5(1)/WF*P2(3), P5(1)/WF*P3(2)/P*IC2(2),
P5(1)/WF*P3(2)/WF2(2), P5(1)/WF*P3(3), P5(1)/WF*P3(4),
P5(1)/WF*RF-IC3(3), P5(1)/WF*RF-LP3(3), P5(1)/WF*RF-P3(3),
P5(1)/WF*RF2(3), P5(1)/WF*RF3(2)/RF*WF2(2), P5(1)/WF*RF3(3),
P5(1)/WF*RF3(4), P5(1)/WF*SP3(3), P5(1)/WF2(3),
P5(1)/WF3(2)/WF2(2), P5(1)/WF3(3), P5(1)/WF4(1)/RF*WF3(3),
P5(1)/WF4(1)/WF*P-SP3(3), P5(1)/WF4(1)/WF*P3(3), P5(2)/P*WF2(3),
P5(2)/P*WF3(3), P5(2)/WF*IC-P3(3), P5(2)/WF*IC3(3),
P5(2)/WF*P3(3), P5(2)/WF3(3), SP*P4(2)/SP*IC2(3), SP*P5(2)/D3(3),
SP*P5(2)/P*WF-SP3(3), SP*P5(2)/WF*P3(3), SP*WF4(2)/WF2(3),
SP*WF5(2)/WF*RF3(3), SP4(1)/D*IC2(3), SP4(1)/D*WF2(3),
SP5(1)/D*SP3(3), SP5(1)/D*WF-IC3(3), SP5(1)/P*SP-D3(3),
SP5(1)/P*WF-SP3(4), SP5(1)/P4(1)/P*WF3(3), SP5(1)/P4(1)/WF*P3(3),
SP5(1)/WF*IC3(4), SP5(1)/WF*P3(4), SP5(1)/WF*SP-P3(3),
SP5(1)/WF3(3), SP5(1)/WF4(1)/WF3(3), WF*D4(2)/D*WF2(3),
WF*D4(2)/D2(3), WF*D4(2)/WF*D2(3), WF*D4(2)/WF*IC2(3),
WF*D5(2)/WF*D-IC3(3), WF*D5(2)/WF*D2(3), WF*D5(2)/WF*D3(3),
WF*D5(2)/WF*IC2(3), WF*D5(2)/WF*IC3(3), WF*P4(2)/WF2(3),
WF*P5(2)/WF*D3(3), WF*P5(2)/WF*IC3(3), WF*P5(2)/WF*P3(3),
WF*P5(2)/WF3(3), WF*RF5(2)/RF*LP3(3), WF*SP4(2)/WF*IC2(3),
WF*SP5(2)/WF*IC-SP3(3), WF*SP5(2)/WF*IC3(3), WF*SP5(2)/WF*SP3(3),
WF*SP5(2)/WF3(3), WF4(1)/D*WF2(3), WF4(1)/WF*D2(3),
WF4(1)/WF*IC2(3), WF5(1)/LP3(3), WF5(1)/WF*D3(3),
WF5(1)/WF*IC3(3), WF5(1)/WF*P3(3), WF5(1)/WF*RF3(3),
WF5(1)/WF*SP3(3), WF5(1)/WF3(2)/WF2(2), WF5(1)/WF3(3)

MC.5A

D*WF-P3(4), D*WF-SP3(4), D*WF3(4), P*D-IC3(4), P*D-SP3(4),
P*D-WF3(4), P*IC-WF3(4), P*LP3(4), P*RF3(4), P*RF4(2)/LP3(2),
P*SP-D3(4), P*SP-IC3(4), P*WF-D3(4), P*WF-IC3(4), P*WF-RF3(4),
P*WF-SP3(4), P*WF3(4), P*WF4(2)/LP*WF3(3), P*WF4(2)/WF3(2),
WF*D-P3(4), WF*D-SP3(4), WF*D3(4), WF*IC3(4), WF*LP-P3(4),
WF*LP3(4), WF*P-D3(4), WF*P-IC3(4), WF*P-RF3(4), WF*P-SP3(4),
WF*P3(4), WF*RF3(4), WF3(4)

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MC.5B	D*IC-WF3(3), D*P-WF3(3), D*SP-WF3(3), D*WF-IC3(3), D*WF-P3(3), D*WF-SP3(3), D*WF3(3), D4(1)/WF*D3(2), LP*P-WF3(3), LP*RF-WF3(3), LP*WF-P3(3), LP*WF-RF3(3), LP*WF3(3), P*D-IC3(3), P*D-SP3(3), P*D-WF3(3), P*D3(3), P*IC-WF3(3), P*LP-WF3(3), P*LP3(3), P*RF-IC3(3), P*RF-LP3(3), P*RF-WF3(3), P*RF3(3), P*SP-D3(3), P*SP-IC3(3), P*SP-LP3(3), P*SP-WF3(3), P*SP3(3), P*WF-D3(3), P*WF-IC3(3), P*WF-LP3(3), P*WF-RF3(3), P*WF-SP3(3), P*WF3(3), P4(1)/P*WF3(2), P4(1)/WF*P3(2), SP*P-WF3(3), SP3(1)/RF*P3(2), WF*D-IC3(3), WF*D-P3(3), WF*D-RF3(3), WF*D-SP3(3), WF*D3(3), WF*IC-D3(3), WF*IC-P3(3), WF*IC3(3), WF*LP-P3(3), WF*LP3(3), WF*P-D3(3), WF*P-IC3(3), WF*P-LP3(3), WF*P-RF3(3), WF*P-SP3(3), WF*P3(3), WF*RF-LP3(3), WF*RF-P3(3), WF*RF-SP3(3), WF*RF3(3), WF*SP-P3(3), WF*SP3(3), WF3(3)
MC.6	D*WF2(3), D*WF2(4), P*D2(3), P*SP-IC2(3), P*WF2(3), WF*D-P2(4), WF*D2(3), WF*IC2(3), WF*P-IC2(3), WF*P-RF2(3), WF*P2(3), WF*P2(4), WF*RF-IC2(3), WF2(3), WF2(4)
P.1	P*IC5(2)
P.2	IC*P2(2), IC*P3(2), IC3(1), IC4(1), P*IC2(2), P*IC3(2), P*IC4(2)
P.3B	IC*P4(2)/P2(2), IC4(1)/P2(2), P*IC-D3(3), P*IC-SP4(3), P*IC4(2)/IC*P2(2), P*IC4(2)/P*IC2(2), P*IC4(3)
P.4B	P*IC4(2)/P*SP-IC2(3)
P.5A	P*IC-SP3(4), P*IC3(4)
P.5B	IC*P3(3), P*IC-D3(3), P*IC3(3)
PP.1	P5(1)/P4(1)/P*D2(2), P5(1)/P4(1)/P*D3(2), P5(1)/P4(1)/P*IC2(2), P5(1)/P4(1)/P3(2), P5(2), P5(2)/P*P3(2), P5(2)/D*P4(2)/D*IC3(2), P5(2)/LP2(2), P5(2)/P*D2(2), P5(2)/P*IC2(2), P5(2)/P2(2), P5(2)/P3(1)/P*IC2(2), P5(2)/RF*P3(2), P5(3)
PP.2	P2(1), P2(2), P3(1), P3(2), P4(1), P4(1)/D3(3), P4(1)/P*D3(3), P4(1)/P2(1), P4(1)/P3(3), P4(2), P5(1)
PP.3A	P4(4), P5(1)/D*IC3(2), P5(1)/D*P3(2), P5(1)/D3(2), P5(1)/LP3(2), P5(1)/P*D3(2), P5(1)/P*IC3(2), P5(1)/P*SP3(2), P5(1)/P3(2), P5(1)/RF*LP3(2), P5(1)/RF*P3(2), P5(1)/RF3(2)
PP.3B	P4(1)/D*IC2(2), P4(1)/D*P2(2), P4(1)/D2(2), P4(1)/IC*D2(2), P4(1)/IC*P2(2), P4(1)/P*D2(2), P4(1)/P*IC2(2), P4(1)/P*RF2(2), P4(1)/P*SP2(2), P4(1)/P2(2), P4(2)/IC*P2(2), P4(2)/P*IC2(2), P4(2)/P*SP2(2), P4(2)/P2(2), P4(2)/SP*IC2(2), P4(3), P5(1)/D*IC2(2), P5(1)/D2(2), P5(1)/IC*D2(2), P5(1)/LP2(2), P5(1)/P*IC2(2), P5(1)/P*RF2(2), P5(1)/P*SP2(2), P5(1)/P2(2), P5(1)/RF*LP2(2), P5(1)/RF*P2(2), P5(1)/RF2(2)
PP.4A	P5(1)/D*SP4(2)/D*SP3(2), P5(1)/P*D4(2)/D*IC2(2), P5(1)/P*SP4(2)/D3(1), P5(1)/P*SP4(2)/D3(2), P5(1)/RF*P4(2)/P*RF2(2), P5(1)/RF*P4(2)/RF2(2), P5(1)/RF4(2)/RF*LP2(2), P5(1)/RF4(2)/RF3(2)
PP.4B	P4(1)/D*IC2(3), P4(1)/D*P-IC2(3), P4(1)/D*P2(3), P4(1)/D*SP2(3), P4(1)/D2(3), P4(1)/IC*P2(3), P4(1)/IC*SP-P2(3), P4(1)/IC2(3), P4(1)/P*D-IC2(3), P4(1)/P*D2(3), P4(1)/P*IC2(3), P4(1)/P*SP-D2(3), P4(1)/P*SP-IC2(3), P4(1)/P2(3),

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	P4(2)/P*D-IC2(3), P4(2)/P*D2(3), P4(2)/P2(3), P5(1)/D*IC2(3), P5(1)/D*IC3(3), P5(1)/D*P3(3), P5(1)/D*SP-P3(4), P5(1)/D*SP3(3), P5(1)/D3(3), P5(1)/IC*P3(3), P5(1)/LP*P2(3), P5(1)/LP*P3(3), P5(1)/LP*RF3(3), P5(1)/LP3(3), P5(1)/P*D-IC3(3), P5(1)/P*D3(2)/D2(2), P5(1)/P*D3(3), P5(1)/P*IC2(3), P5(1)/P*IC3(3), P5(1)/P*RF-LP3(3), P5(1)/P*RF2(4), P5(1)/P*RF3(3), P5(1)/P*SP2(3), P5(1)/P*SP3(3), P5(1)/P2(3), P5(1)/P3(1)/P*IC2(2), P5(1)/P3(3), P5(1)/P4(1)/D*P3(3), P5(1)/P4(1)/D3(3), P5(1)/P4(1)/P*SP-D3(3), P5(1)/RF*LP3(3), P5(1)/RF*P3(3), P5(1)/RF3(1)/RF2(2), P5(1)/RF3(3), P5(2)/RF*LP3(3)
PP.5A	P3(1)/P*D-SP3(3), P3(4)
PP.5B	P3(3)
PP.6	P2(3), P2(4)
RF.1	RF*LP5(3), RF*P-SP5(3), RF*P-WF5(3), RF*P5(2), RF*P5(2)/LP2(2), RF*P5(2)/RF2(2), RF*P5(2)/RF3(2), RF*P5(3), RF*SP-W5(3), RF*SP5(2)/RF3(2), RF*SP5(2)/WF*RF2(2), RF*SP5(3), RF*WF-P5(3), RF*WF-SP5(3), RF*WF5(2), RF*WF5(2)/LP*RF3(2), RF*WF5(2)/RF*LP2(2), RF*WF5(2)/RF*LP3(2), RF*WF5(2)/RF*WF3(2), RF*WF5(2)/RF2(2), RF*WF5(3), RF*W5(2), RF*W5(2)/LP3(2), RF*W5(2)/RF*LP2(2), RF*W5(2)/RF*LP3(2), RF*W5(2)/RF*W2(2), RF*W5(2)/RF*W3(2), RF*W5(3), RF5(1)/RF*P5(2), RF5(1)/RF4(1)/RF*WF3(2), RF5(1)/RF4(1)/RF3(2), RF5(2), RF5(2)/LP*RF2(2), RF5(2)/LP2(2), RF5(2)/LP3(2), RF5(2)/RF*LP3(2), RF5(2)/RF*WF2(2), RF5(2)/RF3(2), RF5(3)
RF.2	RF*LP3(2), RF*LP4(2), RF*P2(2), RF*P3(2), RF*P4(2), RF*SP3(2), RF*SP4(2), RF*WF2(2), RF*WF3(2), RF*WF4(2), RF*W4(2), RF2(1), RF2(2), RF3(1), RF3(2), RF4(1), RF4(2), RF5(1)
RF.3A	RF*LP4(3)/RF*WF3(3), RF*LP4(4), RF*WF-P4(4), RF*WF4(4), RF4(4), RF5(1)/LP*RF3(2), RF5(1)/LP3(2), RF5(1)/RF*LP3(2), RF5(1)/RF*WF3(2), RF5(1)/RF3(2)
RF.3B	RF*LP-P4(3), RF*LP4(2)/RF*LP2(2), RF*LP4(3), RF*P-LP4(3), RF*P-SP4(3), RF*P-WF4(3), RF*P-W4(3), RF*P4(2)/LP2(2), RF*P4(3), RF*SP-WF4(3), RF*SP4(3), RF*W-LP4(3), RF*W-P4(3), RF*WF-LP4(3), RF*WF-P4(3), RF*WF-SP4(3), RF*WF4(2)/LP*WF2(2), RF*WF4(2)/RF*LP2(2), RF*WF4(2)/RF*WF2(2), RF*WF4(2)/RF2(2), RF*WF4(2)/WF*RF2(2), RF*WF4(3), RF*W4(2)/LP2(2), RF*W4(2)/RF*W2(2), RF*W4(3), RF4(1)/LP2(2), RF4(1)/RF2(2), RF4(2)/LP*RF2(2), RF4(2)/LP2(2), RF4(2)/RF2(2), RF4(3), RF5(1)/LP2(2), RF5(1)/RF*LP2(2), RF5(1)/RF2(2)
RF.4A	RF5(1)/RF*P4(2)/RF2(2), RF5(1)/RF4(2)/RF*LP3(2), RF5(1)/RF4(2)/RF*WF2(2), RF5(1)/RF4(2)/RF2(2), RF5(1)/RF4(2)/RF3(2)
RF.4B	RF*P5(2)/LP3(3), RF*P5(2)/RF3(3), RF*SP5(2)/RF*WF3(3), RF*SP5(2)/RF3(3), RF*WF4(2)/RF*WF2(3), RF*WF5(2)/LP*WF3(3), RF*WF5(2)/RF*LP3(3), RF*WF5(2)/RF3(3), RF*W5(2)/RF*LP3(3), RF*W5(2)/RF*W2(3), RF4(1)/LP2(3), RF4(1)/RF*WF2(3), RF4(2)/LP2(3), RF4(2)/RF2(3), RF5(1)/LP*RF3(3), RF5(1)/LP*RF3(4), RF5(1)/LP3(3), RF5(1)/RF*LP2(3), RF5(1)/RF*LP3(2)/LP2(2), RF5(1)/RF*LP3(3), RF5(1)/RF*P3(3), RF5(1)/RF2(3), RF5(1)/RF3(3), RF5(1)/WF*LP3(3), RF5(1)/WF*RF3(3), RF5(2)/LP*RF2(3), RF5(2)/LP*RF3(3), RF5(2)/RF*LP3(3)

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RF.5A	RF*LP3(4), RF*P-WF3(4), RF*P3(4), RF*WF-P3(4), RF*WF3(4), RF3(4)
RF.5B	RF*LP-WF3(3), RF*LP3(3), RF*P-WF3(3), RF*P3(3), RF*SP3(3), RF*WF-LP3(3), RF*WF-P3(3), RF*WF3(3), RF*W3(3), RF3(3)
RF.6	RF*P2(3), RF2(3), RF2(4), RF3(1)/RF*P1(2)
SA.1	LP*RF5(3), MH*W5(2)
SA.2	LP*P2(2), LP*P3(2), LP*P4(2), LP*RF3(2), LP*RF4(2), LP*SP4(2), LP2(2), LP3(1), LP3(2), LP4(1), LP4(2)
SA.3A	LP4(4)
SA.3B	LP*RF4(3), LP4(3)
SA.4B	W5(1)/LP3(3)
SA.5A	LP3(4)
SA.5B	LP*P-RF3(3), LP*P3(3), LP*RF3(3), LP3(3)
SA.6	LP*RF2(4), LP2(4)

C--Scanning Map Negatives on the PDS-1010 Microdensitometer

Turn on the scanner power, lamp, voltage, x-motor, and y-motor. Make sure the Manual Automatic switch is in the Manual mode before turning on the data acquisition system (DAS) power and then the tape unit power. Allow a 30-minute warm-up period. During this wait clean the scanner and tape unit.

Position the scanner upper and lower optics to the aperture (slit) and magnification selected for the material to be scanned. Turn scanner x and y stepping motors to proper gearbox positions for desired $\mu\text{m}/\text{step}$. (Do not use 2.4).

Set the thumbwheel switches for the DAS program location at 400 and the record length at 999. The x-, y-, and manual-data-include switches must be off. Set the x and y $\mu\text{m}/\text{step}$ thumbwheel switches to same values as the stepping motor gearboxes. Set the x and y steps/reading to obtain the selected spacing of density readings. Preset/Reset toggle switches must be at Reset (down) for both x and y. Set stage travel directions, using right-arrow for x and up-arrow for y. Set the 12th (right hand) thumbwheel manual data switch to one, to correspond with the y stage direction. The first ten manual data switches contain the map number, right-justified. The 11th manual data switch is not used for the WRIS programs and is best left at zero. The tape disable switch should be off unless a test is to be made without recording.

When units have warmed up, mount and load a tape. With the Clear/Preslit knob on Clear so that the entire viewing screen is illuminated, focus the upper optics on an empty stage. Then turn the knob (counter-clockwise always) to Preslit and focus the lower optics, making sure the crosshairs are centered in the illuminated circle. Calibrate the densitometer on Preslit as directed on pages 68-70 of the PDS Microdensitometer Technical Manual.

Place the negative on the clean stage, with the north edge away from the operator and west edge toward his right. Tape film at corners, making sure it is flat and tight. Refocus upper and lower optics on a line in the area to be scanned. Scan the west edge to find zero-x, keeping the map edge to the left of the crosshairs in the viewing screen. Press the "Enter x" button so that zeroes show

in the x-position display. Scan the north edge to find zero-y, keeping the map edge above the crosshairs in the viewing screen. Press the "Enter y" button so zeroes show in the y-position display. To minimize the scan area (thus scan time and processing time also), the stage may be rotated by hand to line up the map edges with the x and y zero-axes. Scan the east edge to find the maximum x value in μm , keeping map edge to the right of the crosshairs. Enter the maximum x value in the "Final x" thumbwheel switches. If this number is not a multiple of the $\mu\text{m}/\text{reading}$ for x, each scan line will be ended at the next such multiple. Scan the south edge to find the maximum y value. Divide this value by the $\mu\text{m}/\text{reading}$ for y. If the number divides evenly, add one to the quotient. Otherwise, add two to the quotient. Enter the resulting value in the "Number of Scans" thumbwheel switches.

Drive the stage back to the origin (NW corner of map). Press the DAS Reset button, located below the "Final x" switches so the value of the function counter shows zero. This will also initialize the data acquisition system. The Program Address lights must show 400₈ and the Contents lights must show 240₈. Turn the Clear/Preslit knob to Preslit. Select Auto on the Manual/Auto button. Press the Program Initiate button to start scanner.

When scan is finished, first select Manual on the Manual/Auto button and Clear on the Clear/Preslit knob. Check for reasonable position of NW map corner in relation to crosshairs on viewer. Check for zero values in present x and y position displays and for the correct number of scans in the function counter display. If this was the last scan for this tape, add two manual file marks before rewinding. Otherwise, do not add any file marks. Change the negative and proceed with the next scan job.

VIEWIT: computation of seen areas, slope, and aspect for land-use planning

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Viewit system additions

I. Under certain circumstances, cells which are seen by a few observers may print out in a GMAP as blank. This is because the lowest class, corresponding to the lightest shade of grey, will not show values below 5%. Thus, if there are 20 or more observers, cells seen by only 1 observer will be printed as blank. Where this is undesirable, a new, lighter shade can be printed for cells which are below 5% but are nonzero. This option is enabled by specifying, 'SHOW N Z', for show nonzero. The default case may be restored by specifying 'HIDE N Z'.

II. An upper limit on an observer's angle of view has been added. This is a limit above which the observer is not allowed to look. The default is +90 degrees, which is no limit. To change this, the user should specify 'HI ANGLE=', followed by the desired angle between 0 and 90. In connection with this, a synonym for ZANGLE has been added. Specifying, for example, 'ZANGLE=-45.' will set the lower limit of observation to 45 degrees. This can now be done by specifying 'LO ANGLE=-45.'.

III. A synonym for the OVERLAY command has been added. The same effect can be achieved by specifying 'INTERFACE'. This version of the command may be more easily remembered by those who are using this option in connection with something other than an overlay mapping system.

IV. Three commands have been added to print out tables of statistical information. The information printed out includes the minimum, maximum, mean, standard deviation, variance, skewness and kurtosis. This information can be printed out for the elevation data by specifying 'EL STATS'. The information can be developed and printed out for the count field of cells in the current subrectangle by specifying 'STATS'. If the count field contains the results of one or more visibility analyses, the statistics will only be computed on examined cells. Calculation of statistics can be limited to seen cells alone by specifying 'V STATS'. In other words, V STATS will calculate and print out statistics for cells whose count field is nonzero.

22 August 1975

Additions to the Viewit system:

I. At times a user of the Viewit system may want to give an observer point greater weight than another such point. This can be done by the use of the 'RANK' command. The default observer rank is 1 (one). If the user specifies, 'RANK=2, VIEW, ...' then cells seen by this observer have a count of 2 rather than one added to the value in their numeric field. The value given by the most recent RANK command is multiplied by whatever might otherwise have been stored or added to a particular cell, so that, if a cell would have received an increment of 5 (for 50%) in a weighted visibility analysis, and if the rank is 3, then the cell will receive an increment of 15.

II. Weighted visibility analyses with more than one observer point average the final weighted visibility over all observers. With scattered observer points, this can obscure the results by averaging them away in some areas. The user can avoid this by specifying, 'MAXIMUM'. This will cause the Viewit system to keep the maximum of the previous and present values of the count field of a visible cell, rather than adding the old and new values then later averaging for printout.

The default mode can be restored by specifying, 'AVERAGE'. The MAXIMUM command, although principally intended for use with weighted visibility, can also be used with nonweighted visibility. Combined with the RANK option, MAXIMUM could be used to label each cell with the rank of the highest-ranked observer which saw the cell.

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In summary, the new options added to the Viewit system are:

command	value required?	default	effect
RANK	yes, positive integer	1	Cells seen by an observer will have added (for AVERAGE) or kept if larger (for MAXIMUM) RANK times the number that would otherwise have been added or kept.
MAXIMUM	no	AVERAGE	The maximum of the previous value and the new value is kept for each visible cell.
AVERAGE	no	AVERAGE	The sum of the old and new value is kept for each cell. In the case of weighted maps or the AVG MAP option, this is averaged over all observers for map printout.

The mode should not be changed between AVERAGE and MAXIMUM part-way through a series of visibility analyses, since the results of such an operation would be difficult to interpret.

It is permissible to change the mode at any time. However, the user should understand the effect this will have. The mode is checked when a visibility analysis is done, and either a sum or maximum is kept as explained above. The mode is also checked for map printout requests, and if the mode at the time of the map command is AVERAGE, the system assumes that the mode was AVERAGE for the visibility analyses as well, and divides the contents of the numeric field of each cell by the number of observers (in the case of weighted maps or AVG MAP or GMAP). If the mode at the time of the map command is MAXIMUM, no such division is done.

14 April 1975

Additions to VIEWIT to interface with overlay mapping systems.

One new command has been added to the VIEWIT system, and the use of some existing commands has been extended to allow the user to save the results of VIEWIT options. This information can then be input into overlay mapping systems to develop combined maps of various sorts.

The following commands are used for this new capability:

XMIN, XMAX, YMIN, YMAX, FORMAT, FILE, BY ROWS, BY COLS,
ROW RIGHT, ROW LEFT, COL UP, COL DOWN, BINARY, BCD,
OVERLAY

The four commands XMIN, XMAX, YMIN, YMAX are used to define a subrectangle within the data, as for analysis options of VIEWIT. This subrectangle will be written out to a file when the OVERLAY command is given. (If no subrectangle is specified, the entire data array is written.) The order in which the data is written is determined by the commands BY ROWS, BY COLS, ROW RIGHT, ROW LEFT, COL UP, COL DOWN, which function in exactly the same way here as they do when reading in data with the READ command.

The OVERLAY command causes the contents of the count field of each cell in the current subrectangle to be written out to a file. If the file is to contain card or line images, then BCD should be specified. In this case, a format must be provided by specifying FORMAT. It is not possible to use the same format as that used to read in the data, since the output format must be appropriate to write out integers (that is, it must have 'I' field specifications). The format given should be appropriate to write out one row (or column if BY COLS was specified) of the data.

If BINARY is specified, then the OVERLAY command causes each row (or column if BY COLS) of the current subrectangle to be written out as one binary record.

The FILE command can be used to specify the file to which overlay information will be written. If the FILE command is not given, the default file name of 'OVERLAY.' will be used for output data. If an overlay is written without changing the file name, the information follows previous data written to the same file (if any). If the filename is changed, the next OVERLAY command will write into the beginning of the new file.

2.

In other words, if the user writes an overlay into file A, then another into file B, then returns to file A for the third overlay, the information from the first overlay will be lost.

The OVERLAY command has two forms. The first is simply:

OVERLAY,

This causes the contents of the count field of each cell in the current subrectangle to be written out to the specified or default file. The order and mode of writing are determined by the commands previously mentioned.

The second, optional form of the OVERLAY command provides a label for the overlay data:

OVERLAY='INFORMATION TO LABEL THE FILE',

If the overlay is BCD, then the contents of the string of characters between quotes following the OVERLAY command are written to the overlay file as a card image (80 characters), followed by the data from the current subrectangle. If BINARY was specified, then the characters are written to the file as one 20-word binary record (120 characters), followed by the binary data records.

If the file specified by the FILE command (or the default file) exists as a cataloged or temporary file, that file will be used. Otherwise, a temporary file will be created when the OVERLAY command is given.

The following example illustrates the use of the OVERLAY command:

Assume that the user has read in data using these commands:

```
NROWS = 200, N COLS = 100, Z SCALE = 100.,  
FORMAT = '(25F3.1)', READ,
```

This will read by rows, bottommost row first, from left to right (all defaults) with four cards per row. The data came from file 'ZDATA.' (also a default).

The user then defines a subrectangle and calculates slope class values:

```
XMIN=51, Y MAX=50, SLOPE, TABLE, MAP,
```

After seeing the table and map, the user decides to save this slope class data for further analysis with another program:

3.

```
FILE = 'SLOPE.', FORMAT = '(50I2)',  
COL DOWN, OVERLAY = 'SLOPE CLASS DATA, 50 X 50',
```

After execution of these commands, file 'SLOPE' contains one card image with the label information given between quotes, followed by 50 card images, each with one row's slope class numbers. The topmost card appears first due to the COL DOWN command. The other options remain at their default values.

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This user's guide provides instructions for using VIEWIT—a computerized technique for delineating the terrain visible from a single point or from multiple observer points, and for doing slope and aspect analyses. Results are in tabular or in overlay map form. VIEWIT can do individual view-area, slope, or aspect analyses or combined analyses, and can produce elevation profile charts between any two points in a study area. The guide explains how to prepare data, select available options, and interpret results. VIEWIT is designed to operate on a Univac 1108 computer with Exec-8 operating system. The VIEWIT system is accessible via remote terminals to the USDA Fort Collins Computer Center. For those not having access to this computer facility, the programs are available on request to: Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, California 94701, Attention, Computer Services Librarian. The programs will be copied on a magnetic tape to be supplied by the requestor.

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FOREWORD

VIEWIT is a computerized technique for delineating the terrain visible from a single point or from multiple observer points. The results are produced in either tabular or in overlay map form. VIEWIT can also be used to prepare terrain slope and aspect analyses. In addition, the system may be used to do combined analyses of seen area with aspect relative to the observer points and weighted by the distance to seen areas from observer points. The system will also produce elevation profile charts between any two points in the study area. Besides these basic capabilities, VIEWIT has many options for seen-area analyses and for aspect analyses. The system has been developed over an eight-year period and the original "seen-area" program was published in 1968.¹

The system has been used to help manage and plan lands which are visually important. Examples of applications include timber harvesting, mining, scenic tramway routes, bridge proposals, transportation system alternatives, ski runs, roads, recreation developments, and fuelbreaks. Additionally, VIEWIT is being used to determine visual impact, and terrain slope and aspect information for land-use planning.

VIEWIT provides capabilities for several kinds of analyses of digital terrain data. The basic input to the program is a grid of elevation points representing the area of interest. A second program input is a series of user requests that define the form of the elevation data and cause various operations to be performed. The system then produces tables and maps showing the results of these requests.

VIEWIT is designed to operate on the Univac 1108 computers with Exec-8 operating systems.

What Can VIEWIT Do?

VIEWIT can do these jobs:

1. Verify the consistency of digitized topographic data through the Data Check option and print maps in numeric or gray scales as well as tables showing those cells or cell clusters which do not meet specified tolerances of elevation with their eight neighboring cells.

2. Express in tables showing square miles, acres, and hectares the area within the study unit that can be seen from any single point on the ground or at any

point above the ground level; map the location of these seen areas.

3. Express the above information in composite form from many viewing points within the study area (viewing points may represent alternative roads, trails, or other development systems); map these seen areas on a numerical printout which indicates the number of times each cell is visible from the viewing points; map these seen areas on a gray scale printout which shows all cells visible from 0 to 9 and more than nine times seen in shades of gray; map these seen areas as a percentage of times each cell is seen from the total number of observer positions, and print out in numerical or gray scale maps or both, thereby providing further mapping refinement to cells seen more than 10 times.

4. Evaluate only a portion of a study area (subrectangle) to save time and funds.

5. Evaluate only specified sectors of view such as 0° to 90°, 180° to 220°, or combinations of sectors.

6. Evaluate only specified vertical angles of view.

7. Evaluate only user-specified classes for slope, aspect and elevation analyses.

8. Develop profile printouts in line with (X,Y) coordinates or diagonal to these coordinates in any length specified.

9. Develop tables, numeric maps, and gray shade maps of elevation values.

10. Develop tables, numeric maps, and gray shade maps of slope classes as specified. Slope may be computed by fitting a plane to the eight neighboring cells or by finding the maximum slope to these cells.

11. Develop tables, numeric maps, and gray shade maps of aspects by 36 10-degree classes.

12. Develop tables, numeric maps, and gray shade maps of aspect by eight sectors of 45°, each centered on the principal compass points.

13. Develop tables, numeric maps, and gray shade maps of aspect by eight sectors of 45°, each with weighting from most desirable to least desirable from any direction which is specified to be most desirable.

14. Develop "aspect relative to the observer" (vertical tilting and horizontal rotation of the plane of the grid cell) weighting tables, numeric maps, and gray shade maps. This weighting is one of the functions of "visual magnitude" weighting. It can be done for one viewing point or for many.

15. Develop distance-weighting tables, numeric maps, and gray shade maps. This weighting can be

¹ Amidon, Elliot L., and Gary H. Elsner. 1968. *Delineating landscape view areas . . . a computer approach*. USDA Forest Serv. Res. Note PSW-180, 5 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

adjusted to allow for up to 20 changes in the distance weights. Weights may relate to foreground, middle-ground, and background distances or (e.g.) weights may be specified to give greater weights to middle-ground or the middle areas. It can be done for one viewing point or for many.

16. Develop combined distance, "aspect relative to the observer" and times seen tables, numeric maps, and gray shade maps. These three functions combined measure the relative visual magnitude of each grid cell or the "visual perception sensitivity" of each cell.

Examples of Applications

What are some specific situations and examples in which VIEWIT has been applied? And what parts or options of the program would be useful if you were developing a land-use plan for a visually sensitive unit?

First, after data collection and preparation you would perform a Data Check to verify accuracy. Next, select the key viewing points in the unit and test a combination of distance weighting, "aspect relative to observer weighting," and times seen table which would list the total acreages of each of 10 combined weighting categories and then produce a gray shade map of these combined weightings. This provides a map of the "visual perception sensitivity" of the unit in fine detail. (It would possibly take months to do this work by manual methods—especially to combine the weightings of numerous viewing points.)

In almost every land-use planning situation you would want to develop a slope class map or perhaps several types of slope class maps. For areas that could be logged by tractors the slope class map and the tables could be examined to determine area slopes less than 35 percent. For potential ski areas, slopes between 10 percent and 80 percent could be determined by VIEWIT.

For other uses the aspect options may be valuable. The 45° aspect map with eight weighted sectors might be given highest weighting for northeast exposure to map out best ski area or vegetative regeneration potential or selected microclimatic conditions. Overlay the slope and aspect maps for ski area potential, and potential areas would be immediately apparent. If maximum exposure to sunlight were a criterion, the southwest exposure map printout in gray shades would be most useful. These are just a few of the options that may be helpful.

For an example of project application, consider a power transmission line proposal across a section of

land which you manage. If the proposal is of a general nature in location, you may wish to check its potential visual impact against the "visual perception sensitivity" map prepared in land-use planning (or if this was not done you may want to select key viewing points and produce a printout map). If the proposal is a specific one with tower locations designed, you can set the viewing point at the top of each tower and develop tables and maps which show the acreage on which each tower would visually have impact, or the combined visual impact of all the towers. If the digitized topographic data is already available and you have a computer specialist and a high-speed terminal, this table output and mapping could take just a matter of minutes to prepare in response to the special-use proposal. The same visual impact analysis could quickly be made of a highway proposal, a proposed building, electronic relay, a clearcut block, or a scenic tramway.²

For fire detection planning, the system can be used to map the seen area of existing fixed fire detection stations and to prepare composite seen area maps with additional or reduced numbers of stations. These analyses are then helpful in evaluating the location and height of new stations in specifying a system of stations.

Should You Use VIEWIT?

Before investing time and funds in using VIEWIT, the potential user should answer these questions:

1. Are visual resources of great importance in the proposed project or land-use planning activity? Will they have major effects on decisions?
2. Can the visual analysis be handled through other means with less investment?
3. Does the user have access to a high-speed printer terminal? If not, can the user work with turn-around times involved in mailing of input and output data from other offices; or can work be handled by short details of individuals to such offices?
4. Is the format of output data compatible with other data output? If not, can it be converted to compatible data by manual graphics (outlining areas or coloring in areas of similar output characteristics).
5. If the value of visual analyses is marginal, will the optional outputs, such as slope and aspect maps and tables, offset the marginal values in favor of using VIEWIT?

² Elsner, Gary H. 1971. *Computing visible areas from proposed recreation developments ... a case study*. USDA Forest Serv. Res. Note PSW-246, 10 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

6. Is there high potential for future use of the input data after its initial usage? For instance, would there be possibilities of power transmission, road, timber sale, electronic relay site, etc., proposals within this land unit? If so, visual impacts could be determined within minutes or hours of the proposal at negligible costs.

7. Are there possibilities that several slope and aspect classifications will be needed for planning and design consideration? This program is flexible in producing several kinds of slope and aspect classifications initially or at later dates with no change in stored data.

8. Will computer-generated output data be accepted by management and the public as valued information for decisionmaking? Will quantitative estimates of visual impacts of alternative land uses be

useful in developing land-use or project plans?

This guide provides detailed instructions on how to use the VIEWIT system. Appendix I lists a sample deck of punched cards in the form in which they would be submitted to the computer, and illustrates the computer printout. Appendix II illustrates the use of a preprocessor program with data in a form that cannot be read directly by VIEWIT.

The VIEWIT system is accessible via remote terminals to the USDA Fort Collins Computer Center. For those not having access to this computer facility, the programs are available on request to: Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, California 94701, Attention, Computer Services Librarian. The programs will be copied on a magnetic tape to be supplied by the requestor.

1. IDENTIFYING BOUNDARIES AND CELL SIZE

The first step in using VIEWIT is to decide on the area boundaries. The area boundary may be determined by the boundary of the unit plan and its visual influence area. For instance, a unit plan or project boundary may be limited to primarily the National Forest land on the face of a mountain, but activities on that unit could visually impact a community in the valley below. Therefore, the VIEWIT boundary should extend beyond the planning unit boundary so that the system can accommodate viewing points and allow for any screening terrain that limits the visibility of the project area or land unit.

The second step is to mark the boundary on a USGS map (same scale as later used in data collection such as 1 inch = 1 mile, 1 inch = 2 miles).

1.1 Subdivide Into Grid Cells

Subdivide the rectangle enclosing the area of interest into cells. Each cell is a minimum element for analysis. The cells may be rectangular rather than square. Smaller cells allow a more accurate analysis of seen areas, slope and aspect, but require more data collection effort and more computer costs for analysis.

1.2 Decide on Cell Size and Shape

Decide on the cell size needed for the planning effort. If the computer output map is to be used as an overlay the topographic map at later stages and a high-speed line printer is the output method, the cells should be rectangular to conform to the 1/5 inch x 1/6 inch character type of a printer now.

For example:

	Cell Size =
1 inch = 1 mile	21.33 acres @ 1/5 inch x 1/6 inch
2 inches = 1 mile	5.4 acres @ 1/5 inch x 1/6 inch
1:24,000 (7½-min. quad.)	3.1 acres @ 1/5 inch x 1/6 inch
1:62,500 (15-min. quad.)	20.6 acres @ 1/5 inch x 1/6 inch

To decide on map scale to cell size, consider (a) the amount of detail required for the study; (b) the variation or complexity of terrain; (c) time and dollars available; and (d) whether the data will be used again for more detailed studies with VIEWIT.

The map scale chosen for the VIEWIT analyses should be compatible with that used for other planning variables. It may also be important to choose a cell size and scale which is the same as adjacent planning units.

Not enough experience has been gained as yet to pin down firmly the costs of digitized terrain data, but we have found that the work may be done on a contract basis for approximately 1½ to 2 cents per cell through the use of automatic digitizing equipment. The cost may go as high as 4 cents per cell. Manual digitization (in-service by experienced personnel) has been done at costs of up to 8 cents per cell. This cost data should change rapidly once more experience is gained both with in-service automated digitizing and contracted digitizing of topographic data.

2. PREPARING TERRAIN DATA IN COMPUTER-READABLE FORM

Once the elevation grid location and size have been chosen, the elevations must be put in machine-readable form. This form will usually be punched cards but could be magnetic tape if storage space is a consideration. Frequently, the elevation data will be permanently stored in card form in the office with a tape of this information being used at the computer facility.

No one specific format is required for the elevation data. The user should choose a format that is compact, convenient, and has the required amount of precision. For example, it may be helpful to omit the last (units) digit of elevations to save space on the data medium and to record only the minimum necessary row and column information on each data card.

Many alternative procedures are available for obtaining computer readable digital topographic data (DTD). Topographic maps should be obtained to the same scale for the entire study area. The USGS 7½-minute maps are often the most accurate available. Obtaining these topographic maps is an important first step for any procedure. Some of the basic digitization procedures are:

1. Overlaying a topographic map on a light table with a data grid and coding elevation values directly into each cell.

2. Using automatic digitizer equipment to record contours and their elevation values in line form and utilizing additional software to convert and interpolate to a uniform grid.

3. Obtaining the digital terrain data on magnetic tapes from the U. S. Defense Mapping Agency and using additional software to assist in data verification and interpretation for the study area.

4. Use of outside consultant contract for preparation of digitized topographic data tapes either by manual or automatic digitizing equipment.

2.1 Hand Code Elevation Data

This method involves using a light table and topographic map to obtain computer-readable terrain data. This procedure may be preferable if the study area is small, and individuals with coding expertise are available.

1. Prepare a gridded map overlay (select a rectangular grid, with a ratio of: 1/5 by 1/6 inch if output is by high-speed line printer).

2. Place 7½-minute or 15-minute map on light table and overlay with data grid (tape both to table).

3. Code two-digit (hundreds of feet) elevation values in each cell.

4. Have data sheets cardpunched and verified (OCR forms are a possible option).

5. Use simple computer programs to read, fill the data matrix, and to print an overlay data map to assist in checking of the data for accuracy.

2.2 Digitize Elevation Data

Use digitizers to record contours and elevation values. This procedure is faster and more complex than the procedure just described. It is more appropriate if a large area is to be modeled. It involves handling the information on computer-readable tapes, and thus the operator should have experience in writing programs for reading and writing large data storage tapes. The following basic steps are involved in using this procedure.

1. Digitize contours

2. Check readability of contour tapes

3. Prepare uniform grid data from contour tapes: (a) check a sample of points by overlaying coded elevation map on original topo map; (b) select cell size carefully in order to produce one-to-one overlay maps (1/5 by 1/6 inch if output is by high-speed

line printer).

4. If necessary digitize more contours and add to data base

5. Complete data matrix by interpolation

6. Check accuracy of data matrix

7. Correct data matrix if necessary

2.3 Obtain Digital Terrain Tapes

Digital terrain tapes are available for the continental United States and parts of Alaska. The information has been digitized from 1/250,000-scale USGS topographic maps and interpolated to produce a data print for about every 208.33 feet on the ground. The magnetic tape used is ½-inch IBM compatible, recorded in odd parity, binary at 556 bpi using an inter-record gap of 0.75 inch. Two 2,400 foot reels of tape contain the DTD for one 1/250,000-scale topographic map sheet. Tapes are provided to users for them to copy and return originals to the U. S. Defense Mapping Agency. The DMA data are accurate within about ± 400 feet horizontally and ± 100 feet vertically. Map indexes of available DTD tapes are available from the U. S. Defense Mapping Agency, Topographic Center, Washington, D.C. 20315. Obtaining the tapes from the Agency may take several weeks or a few months. Putting these tapes into usable form for use by the VIEWIT system requires considerable expertise in computer programming.

2.4 Explore Contract Digitizing

Using consultant computer firms for digitizing topographic data has the possibility of being more economical than the other two methods. The larger the area, the more likely that this method will be the best alternative. The following steps are recommended:

1. Develop specifications or modify existing specifications for topographic digitization.

2. Develop a coordinate system grid on the topographic map to be supplied to the contractor.

3. Prepare and execute contract action.

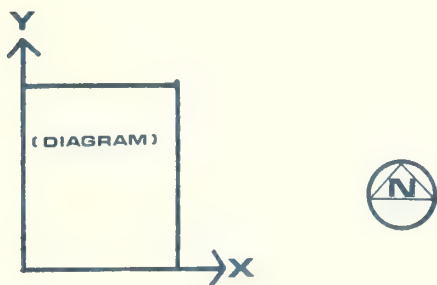
3. IMPLEMENTING VIEWIT

The first following section on data definition and input is intended for the members of the analysis team with programming knowledge and responsibilities. Those

users not involved directly with the computer application may wish to refer to the second section on analysis options in more detail and only review the first section.

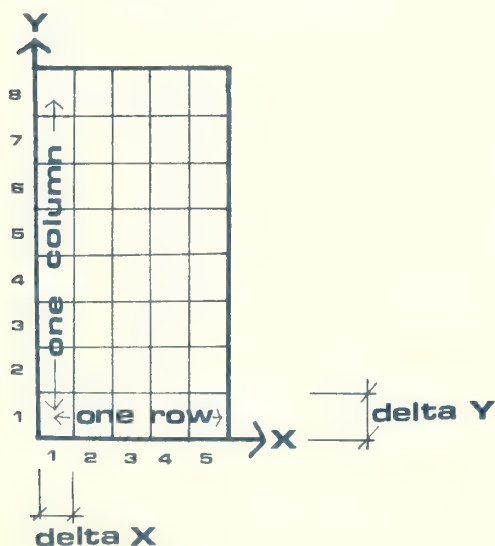
3.1 Data Definition and Input Commands

The system assumes that the area of interest has been defined by a rectangle drawn on a map. The rectangle is oriented so that its lower edge is the X axis, its left edge the Y axis, with +Y pointing north and +X pointing east (fig. 1).



(If the +Y axis of the data grid is not aligned with north, the program can be told to compensate for this, see the ROTATE option in the following table of commands and following discussion.)

This rectangle is divided into cells of a convenient size, and each cell has been assigned an elevation by one of the methods discussed in Section 2. The lower leftmost cell is cell (1,1). The number of cells across the rectangle is the number of columns, NCOLS, and the number of cells from bottom to top is the number of rows, NROWS. Each cell is DELTAX inches wide (on the map) and DELTAY inches high (fig. 2).



The illustration shows a grid with NROWS = 8 and NCOLS = 5. The cell size is given in map inches; the system calculates the ground size from the map scale, M SCALE.

Table 1 lists the commands which define the input elevation data matrix, and specifies which are optional and which are required. The default for optional commands is given.

The system can read the elevation data in a number of different ways. In other words, the format of the data, on cards or tape, is not restricted to one fixed scheme. Therefore, to read the data, the user must specify the format of the data to the system. A number of commands define the format of the data; some of these are required and some, if not specified, cause a default action to take place.

In the simple case in which a data matrix has been punched onto cards by rows, with the lower (most southerly) row on the first card or cards, the user need only specify NROWS, NCOLS, and FORMAT. If elevations have been punched to the nearest 100 feet, with the last two digits omitted from the data, then specifying ZSCALE=100. would cause the program to rescale the elevations to the proper value. All other options would take their default value.

NROWS, NCOLS must be specified. Their product, which is the number of cells in the map, should preferably be less than 60,000 for greatest efficiency. The maximum value of either NROWS or NCOLS is 1000. DELTA X and DELTA Y define the cell size on the map. The default values of one-fifth inch wide by one-sixth inch high will allow the program system to produce maps on a line printer which are exact overlays for the original map; if the values are changed, overlay maps will not be produced.

BY ROWS, BY COLS, ROW RIGHT, ROW LEFT, COL UP, COL DOWN are provided to allow for the fact that different approaches to the problem of digitizing terrain data are equally logical. The default case is BY ROWS, ROW RIGHT, COL UP, which assumes that the data starts on the data medium at the lower left corner, proceeds across the first row to its right, then from left to right across the next row up, etc. If not, choose options that correctly describe the sequence of data points on the data medium. If the number of cells in the map exceeds 60,000, data should be read BY ROWS only; reading it BY COLS will be substantially more expensive in computer time.

Table 1 --Commands defining input elevation data matrix, optional commands, and defaults

Command	Meaning	Required or optional	Default
NROWS	Number of rows	Required	---
NCOLS	Number of columns	Required	---
DELTA X	X size of cell (on map)	Optional	DELTA X = 1/5 inch
DELTA Y	Y size of cell	Optional	DELTA Y = 1/6 inch
BY ROWS	Data appears one row per record or records on the data medium	Optional	BY ROWS is assumed if neither BY ROWS nor BY COLS is specified
BY COLS	Data appears by columns, one col. per record or records	Optional	
BCD	The data is in coded form (cards, or card images on tape or drum)	Optional	BCD is assumed if neither is specified
BINARY	The data appears (on tape or drum) with one binary record per row (or per column if BY COLS was specified)	Optional	
ROW RIGHT	Each row appears on the data medium from left to right (from west to east, as on the map)	Optional	ROW RIGHT is assumed if neither is specified
ROW LEFT	Rows appear on the data medium with the data from right to left (east to west)	Optional	
COL UP	Each column appears on the data medium from bottom to top (south to north)	Optional	COL UP is assumed if neither is specified
COL DOWN	Columns appear from top to bottom (north to south)	Optional	
M SCALE	Map scale	Optional	M SCALE = 24000
FORMAT	A legal Fortran format which will read one row (or one column if BY COLS) of the elevation data from the input medium. The data must be read by F specifications, not I (that is, 3-digit fields must be read as F3.0, not as I3)	Required if data is BCD, ignored if data is BINARY	---
Z SCALE	A multiplier which will be applied to each elevation value read in	Optional	ZSCALE = 1.0
FILE	The name of the Exec-8 file on which the elevation data will be found. This must be cataloged or temporary file attached to the run executing this system.	Optional	The default file name is ZDATA
ROTATE	The angle that North makes clockwise of the +Y axis	Optional	ROTATE = 0
MEMORY	The maximum amount of extra memory the VIEWIT system should ask for from the Exec-8 operating system in order to read in the data	Optional	MEMORY = 60000

BCD is the default and will be the usual case where the data are punched in a form that can be read directly by this system by proper choice of options. If the format of the data is such that reading directly is not possible, the user must write a preprocessor program which will read the data in the user's format and write it in an acceptable format. One such format is binary records, as produced by a Fortran WRITE(IUNIT) list statement. Thus the preprocessor can write the data in this form, and the user can read it into this system by specifying BINARY.

The options mentioned earlier apply here as well as in the BCD case. That is, a binary record may be a row (BY ROWS) or a column (BY COLS). If by rows, the first record may be the lowermost row (COL UP, the default) or the topmost row, in which case the user must specify COL DOWN. The binary data must be in floating point format; this means that the preprocessor must write floating-point numbers.

In some cases the input data matrix may be larger than the memory space in the computer available to the user. If this is the case then the preprocessor should handle the data a row (or a column) at a time with an array dimensioned to the length of a row (or a column) and not for the entire matrix. The VIEWIT system will then automatically handle data matrixes which are larger than available core.

FORMAT is required if the data is BCD. It is a Fortran format, with the enclosing parentheses but without the word "FORMAT," which describes one row or column of the data. More than one card or card image per row or column can be used, so long as the format specifies this. For example, if the data are read by ROWS, and NCOLS=110, with the rightmost digit of the elevations omitted (so elevations are given to the nearest 10 feet and fit in four columns), the following command might describe the data: `FORMAT='(5(20F4.0/),10F4.0).'` This will cause five cards to be read per row.

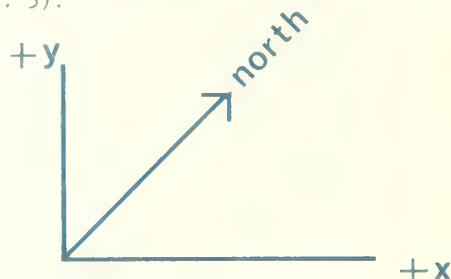
The command, `FORMAT='(20F4.0)'` would also work in that case. (Consult an experienced Fortran programmer if this is confusing.) The format can be up to 120 characters long if necessary.

Z SCALE allows omission of less-significant digits from the data. In the example just described, `Z SCALE = 10.` would be specified to rescale the data. That is, 11,417 feet would be punched as 1142, read in as 1142, and scaled to 11420. ZSCALE applies to both binary and BCD data.

FILE is provided to allow the user to have several data files in the same run. In the usual case, the user will simply create a temporary file named ZDATA and place his data cards thereon.

MSCALE is the reciprocal of the map representative fraction. The default of 24000 is correct for $7\frac{1}{2}$ -minute maps.

ROTATE is provided in case the data grid is not aligned with the compass directions. The default value (ROTATE=0) means that the positive Y axis of the grid is north. For example, if the direction north actually points between +Y and +X, as the drawing shows, then the user would specify ROTATE=45 (fig. 3).



VIEWIT can handle data grids of any size. However, the computer has a limited amount of memory available. If the data fit into this, then they are all kept in memory. If not, portions of the data (called 'pages') are kept in memory, and other portions are stored on auxiliary storage (disk or drum storage).

This mode of operation involves greater costs for transferring data to and from memory, but lesser memory costs. VIEWIT assumes, as a default value, that it can ask the Exec-8 operating system for up to 60,000 words of extra memory to store the data grid. If the data grid has more than 60,000 cells, the paging mode is used. Depending on the total amount of memory available on the computer for the user and on the relative costs of computation, input/output, and memory, it will sometimes be less expensive to process large data grids by setting the value of MEMORY to some larger number. MEMORY cannot be set larger than the total amount of user memory (if the data grid is this large), or the Exec-8 system will kill the user's job.

The final command relating to reading elevation data is READ. This command is given after all data format specifications have been provided and causes the system to ask for sufficient memory space for the data from the Exec VIII supervisory system. When this space is made available, the data are read in as specified. This process of specifying and reading data can only be done once

per program execution. Of course, the program system can be re-executed as many times as desired.

The user should, to summarize, define the extent of the elevation array and its format on the data medium, then cause it to be read. At this point it becomes possible to exercise the analytical options.

3.2 Decide on Data Analysis Options

Two principal classes of analysis can be performed with the data. Each has a number of variations. In addition, several other kinds of analyses are available. The two principal options are (a) visibility and (b) slope/aspect analyses. To understand the use of these options and the various displays of their results, the user must understand the method used by the system.

Two fields or values are associated with each cell of the map. One field is elevation, which is read using the commands discussed earlier. The other field is available for each analysis option to place a number in; the significance of the number varies depending on the option chosen.

The user can display a table showing the frequency of occurrence of each value for all cells by the TABLE command. A numeric map showing the contents of the numeric field for each cell can be printed by the MAP command. A gray-scale map of the same information is produced by the GMAP command.

The contents of the numeric field for each cell is initially zero. It can be reset to zero by the user by the CLEAR command. This is sometimes necessary.

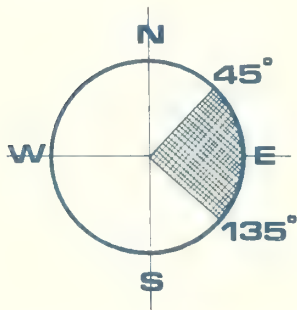
The sequence to be followed is: Perform the desired analysis. Then print a table, or a numeric map, or a gray-scale map, or two of these, or all three if desired, in any order. Then erase the numeric information and perform the next analysis. The exception to this is visibility analysis; it may be desirable to perform several of these before printing a table or map.

3.2.1 Data Specification Commands

The following is a list of the data specification commands associated with data analysis:

<u>Command</u>	<u>Meaning</u>
X MIN	These four commands taken together define a subrectangle within the data upon which analysis will be performed, and maps and tables will be limited to this subrectangle. The default values are X MIN=1, Y MIN=1, X MAX=NCOLS, Y MAX=NROWS, so that the default subrectangle is the entire data array. The subrectangle can be changed at any time, but changing it after an analysis but before printing a map or table will produce useless results. Well thought out use of these commands will save many dollars in computing when the data matrix is large.
X MAX	
Y MIN	
Y MAX	
TITLE	Specifies a run title of up to 120 characters which will be printed at the top of each page. The default is a blank title. (An example is: TITLE = 'MOUNT RUSHMORE PLANNING UNIT')
M TITLE	Specifies a map title of up to 24 characters which will be printed in large block letters before each map. It is printed in two lines of 12 characters each including blanks. The default is 24 blanks. Both TITLE and MTITLE can be changed whenever desired. (An example of MTITLE is: MTITLE = 'TRUCKEE UNITSLOPE MAP.' This instruction will result in the printing of the first 12 characters which are TRUCKEE UNIT on the first line and the second line will then contain the next 9 characters which are SLOPE MAP.)
XOBS	These two commands set an observer point location for visibility analysis. This information must be specified at least once. XOBS and YOBS are in grid co-ordinates.
YOBS	
OBS	Serves as an alternative way to specify the observer location. OBS = (22,14) is equivalent to XOBS = 22,Y OBS = 14.

Command	Meaning	Command	Meaning
RADIUS	Specifies the radius to which visibility will be determined. It is given in miles, and must be specified.		for example, to simulate fire towers, tops of tramways, tops of power transmission towers, airplane or helicopter views. The Z BIAS may be negative to indicate surface excavation. The default value is zero.
NSECT	Disables the azimuth sector feature of visibility analysis. It should be given to turn this feature off or to define a new set of sectors. The default is to examine the full circle.	X END	These commands specify the end point of the line along which profiles will be drawn by the PROFILE command. Profiles begin at the current observer point as set by OBS (or X OBS, Y OBS). To draw a profile (cross-section of the elevation data) from point (13,43) to point (51,20), the user could specify:
SECTOR	Specifies the start and end, in degrees clockwise from North, of an azimuth sector in which visibility analysis is to be performed. Up to 20 such sectors may be defined by successive sector commands. For example, to limit the visibility analysis to the directions from NE to SE, specify: N SECT, SECTOR = (45,135) (fig. 4)	Y END	
		END	OB S=(13,43), END=(51,20), PROFILE,
		NO D W T P	Sets the distance weight function to a standard weight of 1.0 for all distances. It would normally only be needed to redefine the distance weight function.
		T POINT	Specifies a pair of numbers which represent a "turning point" of the distance weight curve. The first number is the distance in miles from the observer, and the second is a weight between 0. and 1.0. The user can define distance weighting functions with up to 20 turning points. The program connects these points with straight line segments. A weight of 1.0 at a distance of 0. from the observer and a weight equal to the last given weight at a distance of infinity are assumed. Turning points must be specified in order of increasing distance.
Z ANGLE	Specifies a <u>vertical</u> angle in degrees relative to the horizontal below which it is assumed that the <u>observer</u> cannot see or which is not appropriate for this analysis. For example, stating Z ANGLE = 0 will have the effect of making all cells at a lower elevation than the observer visible. Z ANGLE can be from -90° to +90°. The default value is -90°, which places no restriction on visibility.	A W ON	Enables weighting by relative aspect in visibility maps. Normally, cells are simply counted as seen or not seen. With weighted visibility (by aspect or distance or both), cells which are seen are given from 0 to 10 points depending on the weighting function.
Z BIAS	Specifies a distance in feet which is added to the observer point elevation for visibility analysis. This can be used,	A W OFF	Turns off weighting by relative aspect.



to return to examining the whole circle, specify N SECT alone.

<u>Command</u>	<u>Meaning</u>	<u>Command</u>	<u>Action</u>
D W ON	Enables weighting visibility by distance, according to the current distance weight function.		of the given direction. The two sides are treated alike (this is not the case for the ASPECT or C ASPECT options). For example, this may be thought of as a sun-illumination analysis if the given angle is the sun's direction or as northeast aspect map if R ASPECT = 45.
D W OFF	Turns off distance weighting. (Initially both relative aspect and distance weighting are off.)		
CLEAR	Sets to zero the contents of the numeric field for each cell in the current subrectangle. The CLEAR command should be used between each type of analysis in the same run. (For example, the numeric field should be cleared between a SLOPE analysis and a VIEW analysis.)	D CHECK	Tests each cell to see if it differs from the average of its eight closest neighbors by more than the tolerance given. If so, a count of the number of times the difference exceeds the given amount is placed in the numeric field. Cells which are greatly different from their neighbors are probably in error. (Normally it is efficient to check the data for gross errors with a large tolerance before using smaller values.)
CLASS	Defines arbitrary classes called 'user classes' that can be used to do slope class, aspect class, or elevation class analyses.	VIEW	Performs a visibility analysis according to the current parameters. The important parameters are observer positions, (OBS), RADIUS, the number of sectors and their positions, Z ANGLE, Z BIAS, and whether or not relative aspect or distance weighting is enabled. For nonweighted visibility, either 0 or 1 is added to the numeric field of each cell. For weighted visibility, an integer from 0 to 10 is added. Thus the contents of each numeric field are accumulated over any number of visibility analyses, and indicate either times seen or weighted times seen. Since these numbers are added, the command CLEAR should be given before beginning a series of visibility analyses to zero the numeric field for each cell. Otherwise, the user may be adding, for example, times seen to slope class, giving a nonsensical result.
N CLASS	Specifies the number of user-defined classes to use in a user-class analysis (U SLOPE, U ASPECT, U ELEV, or UX SLOPE).		

3.2.2 Analysis Commands

The following commands cause various analyses to be performed:

<u>Command</u>	<u>Action</u>
SLOPE	Calculates slope class number for each cell and places it in the numeric field for that cell.
ASPECT	Calculates an aspect class number and stores it for each cell. This option gives 36 classes, each 10 degrees wide, for the greatest resolution of aspect.
C ASPECT	Calculates aspect in eight 45-degree wide classes, each centered on a major compass direction. It provides less resolution than the ASPECT option, but is more useful for some purposes.
R ASPECT	Calculates and stores, for each cell, a number showing the cell's aspect relative to the specified direction. There are eight 22.5-degree wide sectors on each side
	Like all other analytical and output options, VIEW acts on only the current subrectangle.
	U SLOPE Causes the VIEWIT system to perform a slope class analysis using user-defined classes.
	U ASPECT Causes an aspect class analysis to be performed using user-defined classes.

<u>Command</u>	<u>Meaning</u>
U ELEV	Causes the system to classify elevations by the user-defined classes.
For U SLOPE, the contents of the user-defined classes are interpreted as slopes in percent (for example, 100.0 means a 45-degree slope). For U ASPECT, the numbers are interpreted as compass directions (0 to 360) in degrees. For U ELEV, the numbers are interpreted as elevations in feet.	
X SLOPE	Calculates slope class numbers using a nonaveraging method of calculating slope.
U X SLOPE	Calculates slope class numbers using nonaveraging slope calculation, according to user-specified classes.

3.2.3 Display Option Commands

The following commands are for the display options:

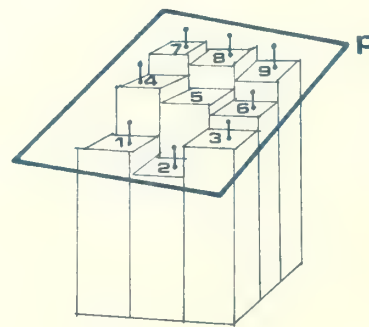
<u>Command</u>	<u>Meaning</u>
TABLE	Prints a table showing the distribution of the contents of the numeric field of all cells in the current subrectangle. An appropriate explanatory heading is printed, depending on the operation last performed on the data. (The user will probably find this option useful for all of the types of analyses.)
MAP	Prints a numeric map of the contents of the count field for each cell in the current subrectangle. The numbers may be slope class, times seen, etc., depending on the last operation performed. An appropriate heading is printed.
AVG MAP	Causes subsequent MAP commands to print maps of times seen with each cell's value presented as a percent of the numbers of observers. This is especially useful if there are 10 or more observer points.
NUM MAP	Cancels the AVG MAP command and returns the MAP command to the default mode of printing the actual number of times seen for each cell.

<u>Command</u>	<u>Meaning</u>
G MAP	Prints a gray-shaded map of the numeric field of each cell. This gives the same information as the MAP command in a form which is more understandable as a whole, especially when seen from a distance.
D PRINT	Causes the actual elevations of each cell in the current subrectangle to be printed in a coded form. This is useful primarily for data checking.
PROFILE	Prints a cross-section or profile of the elevation data from the current observer point to the current end point. The cross-section is not to scale (it has exaggerated vertical scale) but is useful for data checking or for getting a sense of the shape of the terrain or for determining high or low points on a specified route for further view analysis.

3.2.4 Description of Analysis Options

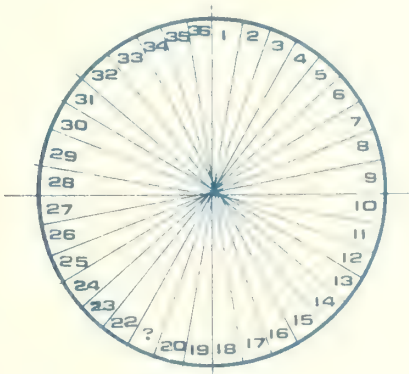
The following sections explain the analysis options in more detail.

SLOPE calculates the slope of each cell by fitting a plane surface to its eight nearest neighbors. This plane is a 'best fit' in the sense that it minimizes the sum of (distances from the plane to the cells) squared. Slope classes are 10 percent each, so that a slope of 0 to 10 percent is the first class, 10 to 20 percent is the second class, and so forth. Slope class numbers are stored in the numeric field for each cell where they can be examined with one or another of the printout options (fig. 5).

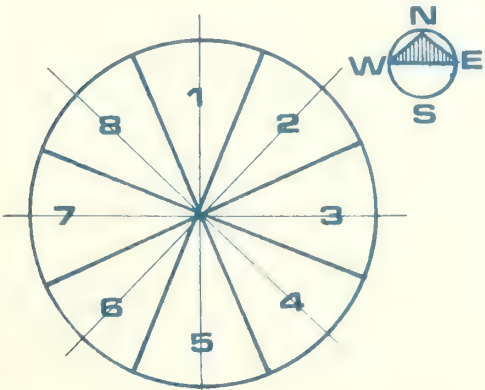


Cell 5 is the cell whose slope is wanted. A plane P is chosen through 5 so that the sum of the squares of the distances from the centers of each of the eight surrounding cells to the plane (drawn above as short vertical lines) is a minimum. The slope of the plane is the slope for the center cell.

Each of the aspect options starts by first finding the best-fit plane at each cell, as the diagram above. Then, the aspect of the cell is the direction in which this plane slopes most rapidly. (A cell with no slope does not have an aspect at all.) For ASPECT, the aspects are divided into 36 classes (each 10 degrees) and the class numbers stored for each cell (fig. 6).

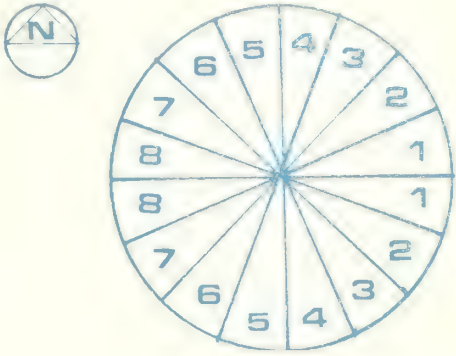


The C ASPECT option divides the circle into eight 45-degree sectors centered on the principal compass points. The class numbers can be printed with TABLE, MAP or G MAP (fig. 7).



This option would be used chiefly to develop shaded maps to indicate aspect by traditional sectors of direction.

The R ASPECT option requires that the user specify a direction (in degrees from north) and calculates the aspect of each cell relative to the given direction. Angles an equal distance on either side of the given direction are treated alike. There are eight classes, each 22.5° wide, from the given angle on either side to opposite the given angle. The following diagram shows the division of the circle into relative aspect classes assuming the user has specified R ASPECT = 90 (fig. 8).



This option would be used mainly to develop weighting of cells from most desirable to least desirable aspects, such as, northeast for snow retention or optimum vegetative regeneration, southeast for campgrounds (early morning sun and protection from late afternoon sun).

The information developed by R ASPECT can be displayed with TABLE, MAP or G MAP. The G MAP display is especially useful with this aspect option. (Gray-scale maps with the other aspect options are not satisfactory because the mind does not want to see the darkest class as being just next to the lightest class.) In particular, a map of the information from the R ASPECT analysis can be considered to be an approximate sun-illumination map of the area under consideration, where the direction specified by the user is the sun's azimuth. (Shading of one cell by another is not considered in this analysis--only the aspect of each cell.)

For both R ASPECT and C ASPECT, class zero is used for cells with no aspect.

Different investigators may have different ideas as to what constitutes a good set of slope or aspect classes. Therefore, the capability of user-defined classes has been added to VIEWIT. These classes can be used for slope, aspect or elevation analysis. To use this option, first define the classes. There can be up to 50 user-defined classes. The user who intends to print gray-shaded maps should not define more than nine classes, however, because only that many distinct shades of gray can be produced. (All numbers from 9 on up will print as the darkest shade.)

Classes are defined by use of the CLASS command. This has a form that is slightly different from other commands, in that it takes a 'subscript' (a number specifying which class is being defined) after the word 'CLASS.' The following is an example of the definition of some classes that might be used for slope analysis:

```
CLASS(1)=(0,35),CLASS(2)=(35.,100.),CLASS(3)=
(100,1000),NCLASS=3,
```

This example specifies that the first user class is from 0 to 35, the second from 35 to 100, and the third from 100 to 1000. It is also necessary to specify NCLASS--this tells VIEWIT to use the first NCLASS classes (in the example, 3) to do its analyses, maps and tables.

The CLASS command simply accepts any pair of numbers as a value for the specified class. The interpretation of the numbers depends on the analysis to be performed. For slope, the numbers are interpreted as slopes in percent. If the classes defined in the example above were used for slope class analysis, cells whose slope fell between 0 and 35 percent would be given a slope class number of 1, cells with slopes between 35 and 100 percent a class number of 2, and so forth.

For aspect, the class numbers are interpreted as compass directions in degrees. For example, to pick out cells whose aspect was mostly north, the following commands might be used:

```
CLASS(1)=(350,360),CLASS(2)=(0,10),NCLASS=2,
U ASPECT,MAP,
```

All cells with aspects in the range 350 to 360 degrees would be given a class number of 1, all cells from 0 to 10 degrees, a class number of 2, and all other cells would be given the default class number of zero (which means 'not in any defined class').

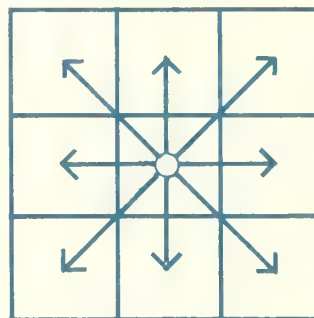
For elevation class analysis, the class numbers are taken to be elevations in feet. The following example shows how a user might pick out a band of elevations and break it into several subbands:

```
CLASS(1)=(5000,5500),CLASS(2)=(5500,6000),
CLASS(3)=(6000,6500),NCLASS=3,U ELEV,TABLE,
MAP,
```

These examples illustrate a number of points about class values. Each class has two values associated with it, which are taken to be the lower and upper limit of the class. So, the second number should be larger than the first (no check is made for this, but a class defined backwards will never be found to have anything in it). Classes need not be

defined in increasing order, and there may be gaps between them. Classes may overlap, but if they do, a cell will be assigned to the lowest-numbered class in which it falls. Cells which do not fall in any of the first NCLASS classes will be given a class number of zero, which will print as '0' on the map produced by the MAP command, or as a blank on the GMAP gray-scale map.

For some uses, such as soil stability analyses, the method of calculating slope with a best-fit plane over nine cells averages out too much detail in the terrain. For such cases, the maximum slope analysis option, XSLOPE, may be used. This option calculates the slope from a cell to each of the eight surrounding cells, and keeps the largest of these eight numbers (fig. 9).



This slope is then placed in one of the standard 10% slope classes. Alternatively, the U X SLOPE option calculates a maximum slope as shown previously, and then classifies it according to the current set of user-specified classes.

The XSLOPE and U X SLOPE analyses give what is essentially a worst-case slope classification.

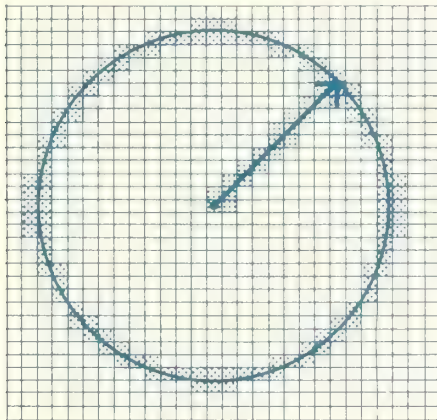
For example, assume that three logging techniques are available. The first is applicable to flat and nearly flat terrain, the second to moderate slopes, and the third to steep slopes. The following commands will isolate each of these slope classes and print a map:

```
CLASS(1)=(0,10),CLASS(2)=(10,25),CLASS(3)=
(25,1000),NCLASS=3, U X SLOPE, MAP,
```

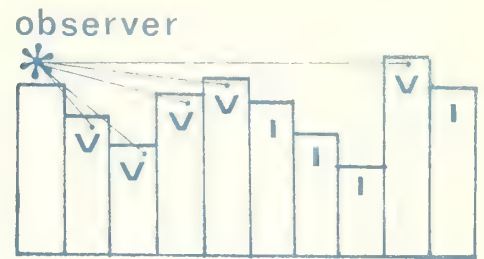
The data check option, D CHECK, calculates the average elevation of the eight cells around each cell. If the elevation of the cell differs from this average (either by being higher or lower) by more than the value specified by the user, a class number is stored for that cell. For example, if the user gave the command, DCHECK = 200., then cells whose elevations were within 200 feet of the average of their neighbors would have their numeric fields filled with a zero. Cells whose elevations differed by 200 to 400 feet

VIEW may be the most important analysis capability for most users of this system. It produces visibility information that can be displayed as a seen area map, visible frequency map, or weighted visibility map, depending on the options chosen.

A diagram illustrates a matrix of data with an observer point, circle, and one ray (fig. 10).



Elevations along a ray are determined and some cells are shown to be visible and some not (fig. 11).



The CLEAR ensures that the numeric field has all zeroes. Then an observer position is defined and a visibility analysis performed for a radius of $\frac{1}{4}$ miles. The user could have printed a table or map here, but elected to perform another analysis for a new observer position. Since the radius of examination was not changed, it remained at 1.25 miles for the second analysis.

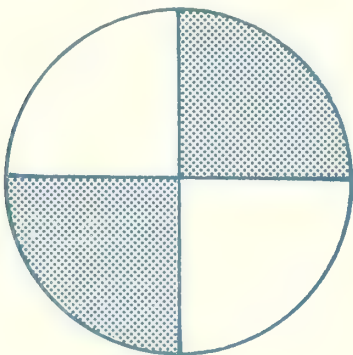
A number of options restrict or modify the visibility analysis and affect the form of display of the results:

1. Z ANGLE specifies an elevation/depression angle below which cells are to be considered invisible for the particular observer. This is initially -90° , which means no restriction. For example, if the observer is considered to be on a flat plane, so that cells at a lower elevation are invisible, set Z ANGLE to 0. This command may be used to limit the vertical angle of view from automobiles or buildings.
2. Z BIAS can be used to raise or lower the observer position. The number given by Z BIAS is added to the elevation found in the cell as (X OBS, Y OBS) for the visibility analysis. (The number is not permanently added to the elevation of the specified observer cell.) This option has been used to show the effect on visibility of ski lift towers, aerial tramways, power transmission lines, and similar structures. It may also be used to simulate observation points from airplanes and helicopters.

The N SECT and SECTOR commands can be used to limit the visibility analysis to user-specified azimuth sectors rather than a full 360° circle. N SECT specifies no sectors, which is the default case. It can be used to return from sectorized mode to an examination of the entire circle, or to define a new set of sectors. After N SECT is specified, each SECTOR command specifies a pair of numbers which is the start and end azimuth (in degrees from north) of a sector to be examined. There can be up to 20 such sectors. For example, the commands:

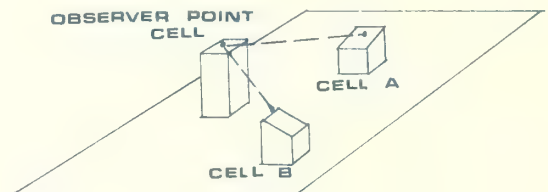
N SECT, SECTOR=(0.,90.), SECTOR = (180.,270.),

will cause all subsequent visibility analyses to be performed only on azimuths from 0° to 90° and from 180° to 270° (i.e., the shaded areas would be examined for visibility and the blank areas would not) (fig. 12).



The Z ANGLE, Z BIAS, and SECTOR options can be used individually or together for any one of several observer points in a series, or for more than one or all. Different observer points can have different values for these options, or the same. The user must only remember that the value specified remains the same until it is changed.

The other set of options for visibility analysis are the weighting options. The first option is weighting by aspect relative to the observer. This function is enabled by A W ON and disabled by A W OFF. Initially it is disabled. With this option, the system calculates the aspect of each cell which is determined to be visible as explained earlier. This aspect is converted to an aspect relative to the observer, taking into account the aspect of the seen cell, elevation of that cell, and elevation of the observer. In most cases, the observer will see the cell somewhat obliquely rather than head-on. Consequently the apparent area of the seen cell will be reduced. Each cell is assigned a maximum of 10 points, and this is scaled according to the relative aspect. That is, if the cell is turned partially away from the observer so that its apparent area is only one-half of its actual area, it receives five points. Cells turned at 90° to the observer, so that they are seen edge-on, and cells which face away from the observer, receive zero points. (Thus zero may indicate cells seen in silhouette that may be of major importance in the analysis of the terrain (fig. 13).)



Cell A is turned at about 45° to the line from the observer in the horizontal plane, and about the same in the vertical plane. It would receive about five points. Cell B is oriented away from the observer and would receive zero points.

The score for each cell, zero to 10, is added to the numeric field for that cell. After weighted visibility analyses have been performed for five observer points, each cell could have a count of zero to 50. A count of 10 could indicate that a cell was seen directly head-on by one observer, and not by others at all, or more likely, that the cell was seen obliquely by several observers.

The numbers developed by this process can be displayed by TABLE or MAP, as before. Because only 10 distinct gray shades are produced on the line-printer, however, a slightly different approach is used for G MAP: The score for each cell is divided by the number of observer points for display purposes. Thus the number displayed by G MAP will always be in the range of zero to 10. This can be considered to be an average of weighted visibility over observers.

Weighted visibility and simple visibility analyses should not be combined in a single series. The system will allow such a combination, but the results will be difficult to interpret. The CLEAR command should always be used between different kinds of analyses.

The Z ANGLE, Z BIAS, and SECTOR options can be used for one or more observer points for weighted visibility analysis, and have the same effects as in the simple case.

The second kind of weighting is distance weighting. This can be used alone or in combination with relative-aspect weighting. The option allows the visibility of a cell to be weighted by its distance from the observer. To do so, the user must define a distance-weight function which expresses the desired relationship between distance and visibility.

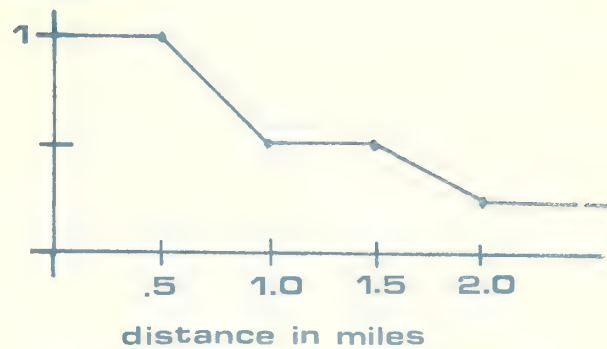
Rather than having a limited set of distance functions, the system allows the user to define any function within certain limits. Distance-weight functions are defined by approximating them by straight line segments and specifying the intersections of these line segments. These points, which are called turning points of the function, are defined by the T POINT command. A maximum of 20 such turning points may be used to define each distance-weighting function. The program assumes that a distance of zero always has a weight of 1.0, and that the last user-specified weight extends outward to an infinite distance.

Assume that the user issues these commands:

```
NO D W T P, T POINT =(.5,1.0),T POINT = (1.0,
0.5), T POINT =(1.5,0.5),T POINT=(2.0,0.25),
D W ON,
```

The first command, NO D W T P, specifies no distance-weight turning points. This sets the distance-weight function back to its initial value of 1.0 for all distances. Then the user specifies four points on the function and enables distance weighting (fig. 14).

weight



The line is automatically connected to weight 1 at distance zero and the last weight given is extended outward.

This example also illustrates two rules for the definition of distance-weight functions: (a) weights are numbers between zero and 1.0 inclusive; (b) turning points must be defined from smallest distances to greater distances, otherwise the weighting will not function properly.

When a distance-weight function is defined, D W ON enables weighting by distance. As in relative-aspect weighting, each cell receives a score of zero to 10 points. A weight of 1.0 corresponds to 10 points, a weight of .5 to 5 points, and so forth. This information can be printed with TABLE or MAP, or displayed as an average weighted visibility with G MAP as in the case of relative-aspect weighting.

If the user specifies both relative-aspect and distance weighting, the two weighting processes are carried out independently. Each process produces a number between 0 and 1.0. In the case of relative-aspect weighting, this number is the apparent area of the cell as a fraction of its area if seen head-on. In distance weighting, the number is derived from the user's function. Then these two numbers are multiplied to produce a final weight in the range of 0 to 1.0. This weight is then converted to 10 classes from 1 to 10 and added to the contents of the numeric field of the cell in question.

Either relative-aspect or distance weighting or both can be used for any observer point or points in a series of visibility analyses, but neither should be combined with a simple visibility analysis for the reasons explained earlier. (A series of visibility analyses ends when the user issues a CLEAR command; up to that point numbers accumulate in the numeric fields for each analysis.)

3.2.5 Type of Input Expected for Each Command

This system provides for the free-form input of user commands. Commands need not start or end in any particular card column, they may continue across card boundaries, and blanks are usually ignored. Each command is a word of several letters. Certain commands require that the word be set equal to a value. The three types of values are: numbers, strings of characters, and pairs of numbers. An example follows:

```
NROWS=50, NCOLS = 40, BCD, FORMAT = '(40F2.0)',
Z SCALE = 100.0, READ, RADIUS = 1.50, MTITLE =
'SMALL MAP',
OBS=( 12, 33.), VIEW, MAP,           OBS = (12,
34),VIEW,MTITLE = '',MAP,
```

This example defines an elevation array of 50 by 40 locations, specifies that it is in card image form (which is the default and need not have been specified), and that the data are in 40 consecutive two-digit locations on each card. The elevations as read from the cards are to be multiplied by 100. The data are read by using the defaults of BY ROWS, etc. A simple visibility analysis is then performed with the observer at (12,33) and a map of times seen printed with the title SMALL MAP. This analysis is repeated for a new observer.

The example illustrates these points: Certain commands such as BCD and READ expect no value; any value given will be ignored. Other commands expect values of a certain type. Numeric values may have any of the forms NNN, NNN.NNN, .NNN, or any of these preceded by a minus sign. If the program expects an integer, the number given will be rounded to the nearest integer. Character strings are enclosed by single quotes, and only inside the quotes are blanks significant. (Only TITLE, M TITLE FORMAT, FILE and COMMENT expect character string values.) Commands are separated by commas, and extra commas between commands are ignored. Card boundaries are ignored (and as a consequence, the last command on each card must have a trailing comma, or there must be a comma before the first command on the next card, or both). Pairs of numbers are enclosed by parentheses and separated by a comma; otherwise, their form is the same as for numbers standing alone.

Commands may also have a subscript, which is a number in parenthesis following the command name. Currently this is only used by the 'CLASS' command. If a subscript is used with any other command it will be ignored and a warning message printed.

The character '\$' has a special function in strings of characters--it acts as a tab to the next set of 12 characters. This is intended

for use with the M TITLE and MESSAGE commands. Map titles are printed as two lines of 12 characters each. To print the title USER-CLASS SLOPE MAP on two lines, the user could use the command

```
MTITLE='USER-CLASS  SLOPE MAP',
```

where the two blanks after the word 'CLASS' ensure that the word 'SLOPE' will start on the next line, or more simply, the user could say

```
MTITLE='USER-CLASS$SLOPE MAP',
```

which would save having to count characters.

All user commands, whether they expect a value, and if so what type, are listed here. Because blanks are ignored, the command Z SCALE can be given as ZSCALE or Z S C A L E, and the command G MAP may be GMAP or G MAP and so forth. The form that is shown is considered most readable.

Command	Value expected
NROWS	number (integer)
NCOLS	number (integer)
DELTA X	number
DELTA Y	number
M SCALE	number
X MIN	number (integer)
X MAX	number (integer)
Y MIN	number (integer)
Y MAX	number (integer)
BY ROWS	none
BY COLS	none
BINARY	none
BCD	none
ROW LEFT	none
ROW RIGHT	none
COL UP	none
COL DOWN	none
FORMAT	character string
TITLE	character string
M TITLE	character string
X OBS	number (integer)
Y OBS	number (integer)
OBS	pair of numbers (integers)
Z SCALE	number
RADIUS	number
N SECT	none
SECTOR	pair of numbers (integers)
Z ANGLE	number
Z BIAS	number
FILE	character string
X END	number (integer)
Y END	number (integer)
END	pair of numbers (integers)
NO D W T P	none
T POINT	pair of numbers
A W ON	none
A W OFF	none

Command	Value expected
D W ON	none
D W OFF	none
READ	none
CLASS	pair of numbers
N CLASS	number
X SLOPE	none
SLOPE	none
U SLOPE	none
U X SLOPE	none
ASPECT	none
U ASPECT	none
U ELEV	none
VIEW	none
MAP	none
AVG MAP	none
NUM MAP	none
CLEAR	none
TABLE	none
G MAP	none
D CHECK	number
D PRINT	none
PROFILE	none
C ASPECT	none
R ASPECT	number
COMMENT	character string

4. DEMAND TERMINAL USE

The VIEWIT system may be used in either batch or demand computing. Output on line printers may be requested from small demand terminals.

In a batch run, the system echoes each input card as it is read in, and then prints each command as it is carried out. If the user violates the rules of the command language, there are a number of error messages which are reasonably self-explanatory: An error message will be printed, along with the card containing the offending command, with an '*' printed in the vicinity of the error. In case of an error, the system stops execution. Execution also stops when there are no more commands.

In a demand run, the echoing of input is suppressed. Only the actual result of command execution is printed. Also, if VIEWIT is being run in a demand mode, when an error occurs the system asks the user to re-enter the command or commands, rather than stopping execution as it does in batch mode.

Because VIEWIT uses a relatively large amount of memory and other computer resources while handling a massive problem, it should be used on a demand terminal with a certain amount of caution. Gray-scale maps and other large overlay maps take a large amount of time to type out on a small demand terminal. However, many offices do not have easy access to any other kind of terminal. Therefore, certain features of VIEWIT have been designed

for demand use. These features allow the user to do analyses and print out tables and small maps on demand terminals and to divert large maps and other output to high-speed line printers at other locations.

In demand mode, most user input errors are caught by the system, and the user can correct them (in batch mode, the VIEWIT system simply stops when an error is detected). Several additional user commands have been defined for demand users:

Command	Meaning
STOP	Stops execution of the system.
DIVERT	Creates a file and causes all printed output from VIEWIT to be sent to the file instead of being printed out at the demand terminal.
SEND	Causes the file created by a preceding DIVERT command to be sent to a batch terminal to be printed out on a line printer; the user specifies which batch site by setting SEND to the site ID (see the example below).
MESSAGE	Prints a string of characters in large letter form, with up to 10 lines of 12 characters each. This command is intended for use with DIVERT and SEND to label the batch output. Also, MESSAGE can be used at any time (in either demand or batch mode) to print out large letters for any purpose.

The DIVERT and SEND commands are especially useful for map output. The following example shows how a user might do a slope class analysis and then print the slope class map at a high-speed site:

SLOPE, TABLE,

(at this point the user inspects the table and decides that the map will be worth printing)

DIVERT, MESSAGE='SEND TO\$JONES AT\$TAHOE NF',
TABLE,MAP,SEND='FCR014',

The 'DIVERT' command creates a file, and puts the words VIEWIT OUTPUT at its beginning in large letters. The 'MESSAGE' command in the example prints in large letters:

SEND TO
JONES AT
TAHOE NF

The TABLE and MAP commands print another copy of the slope class table, and a slope class map. Then the SEND command causes the file containing the output produced by all of the above to be printed at batch site FCR014, which happens to be the FCCC site ID for the high-speed terminal in the Forest Service's California Regional Office in San Francisco.

If an error occurs after a 'DIVERT' but before a 'SEND', the error message will go into the file rather than to the terminal. The recommended way to use these two commands is to type in DIVERT, then display commands, then SEND, all on one line. Inspect the line for errors before hitting the carriage return key; if there are errors, cancel the line (control X) and retype it.

If something seems to have happened after a 'DIVERT', output can be returned to the terminal by typing in the transparent control statement:

```
@@BRKPT PRINT@
```

The DIVERT command creates a file with a name of the form PRnnnnnnnnnn, where nnnnnnnnn is a 10-digit number. This is a cataloged public file; normally the SEND command will free it and send it to the specified site with a @SYM operation. If SEND fails, or for whatever reason, the user could explicitly FREE and SYM the file, or delete it, or examine it with the interactive editor.

In other words, the file created by DIVERT is an ordinary Exec-8 file. It can be operated on in any way that any line image file (called 'SDFF' file) can be operated on.

Another feature added to VIEWIT for demand use makes it possible for the user to interrupt an operation in progress. This is particularly useful if the user begins to print a long table or map and then decides that he does not want to see it. This is done as follows: First, hold down the 'BREAK' key on the terminal for a moment. This will stop printing and cause the Exec-8 system to print out a message: '*OUTPUT INTERRUPT*'. At this point the user should type in '@@X C' followed by a carriage return. This will generate an interrupt which will cause the VIEWIT system to stop execution of the command in progress and ask the user to submit a new command. (Several lines of the map or table being printed may appear before the interrupt takes effect.)

The Exec-8 rules for the automatic assignment of files are different for demand and batch. Therefore, the demand user should explicitly assign the two files needed to operate VIEWIT. The recommended control card sequence to use is:

```
@ASG,A PSW:VIEWIT.  
@ASG,A PSW:LOG.  
@FREE PSW:LOG.  
@XQT PSW:VIEWIT.
```

(Either '@ASG' statement may result in the message 'WAITING FOR FACILITY'. In this case the demand user must wait until the Exec-8 system makes the file available. This will normally take only a few minutes.)

APPENDIX I

This appendix shows a simple VIEWIT run in which the data is read directly by the system. The printouts show first, a listing of the cards to be submitted to the computer, just as they would appear in the input deck. This is followed by the actual computer output resulting from the submission of these cards.

The printouts demonstrate how the elevation data is placed on a file named ZDATA by the use of the @DATA control card. The user commands follow the @XQT card which calls the VIEWIT system into execution. These commands first specify the size and form of the elevation data and cause it to be read. They then perform a number of simple analyses.

```

@HDG ***DEMONSTRATION RUN***
@MSG,N DATA INPUT IS FROM CARDS
@MSG,T ZDATA, . CREATE A TEMPORARY FILE, 'ZDATA.'
@DATA,I ZDATA, . INSERT DATA CARD IMAGES INTO FILE 'ZDATA.'
*****
* DATA CARDS GO HERE *
*****
@END . THIS CARD IS NEEDED TO STOP @DATA FROM INSERTING CARDS.
@XQT PS=VIEWIT, . NOW RUN THE VIEWIT SYSTEM
COMMENT='FIRST DEFINE AND READ THE DATA',
NROWS=52, NCOLS=36, ZSCALE=100., FORMAT='(36F2.0)', COL 30AS, HEAD,
COMMENT='NOTE USE OF ZSCALE TO BRING THE DATA TO THE RIGHT RANGE',
COMMENT='DEFAULTS SUCH AS ROW RIGHT, BCD, MSCALE=24000 HAVE BEEN 'SEQ.',
COMMENT='NOW DEFINE AN OBSERVER POINT AND DO A VISIBILITY ANALYSIS',
MTITLE='SEEN AREAS$MAP',
OBS=(22,18),RADIUS=1.5, VIEW, COMMENT='NOW PRINT A NUMERIC MAP',
MAP, COMMENT='AND A GREY SCALE MAP', MTITLE='',
MESSAGE='GREY SCALES$SEEN AREAS$MAP', GMAP,
COMMENT='ADD A SECOND OBSERVER',OBS=(20,20),VIEW,
MTITLE='TIMES SEEN$MAP',MAP,
COMMENT='NOW WITH THE AVERAGE MAP OPTION INSTEAD.',
AVG MAP, MTITLE='AVERAGE MAP$TIMES SEEN', MAP, MTITLE='',
MESSAGE='GREY SCALE$TIMES SEEN$AVERAGE MAP', GMAP, NUM MAP,
COMMENT='NUM MAP COMMAND SET MAP MODE BACK TO THE DEFAULT OF NUMERIC MAPS OF TIMES SEEN',
COMMENT='CLEAR COUNT FIELD AND DO A NEW SET OF VISIBILITY ANALYSES.',
MTITLE='SUBRECTANGLE', CLEAR, X MIN= 10, YMIN=10, YMAX=30,
COMMENT='NOW ALL OPTIONS AFFECT ONLY THIS SUBRECTANGLE.', VIEW, MAP, TABLE,
COMMENT='NOW GO BACK TO THE WHOLE DATA GRID', XMIN=1, YMIN=1, XMAX=36, YMAX=52,
COMMENT='EXAMINE ONLY CERTAIN AZIMUTH SECTORS FOR VISIBILITY',
CLEAR, MTITLE='SECTORS$MAP', SECTOR=(90,180), SECTOR=(225,315), VIEW,
MAP, CLEAR, COMMENT='RESET TO SCAN THE WHOLE CIRCLE', N SECT,
COMMENT='PRINT A CROSS-SECTIONAL PROFILE', END=(37,52), PROFILE,
MTITLE='SLOPE$MAP', COMMENT='PRINT A SLOPE CLASS MAP', SLOPE, TABLE, MAP, GMAP,
COMMENT='FIND SLOPE CLASSES BY THE MAXIMUM SLOPE METHOD RATHER THAN THE AVERAGING METHOD USED BEFORE', X SLOPE, TABLE,
MTITLE='MAXIMUM$SLOPE MAP', MAP, GMAP,
COMMENT='AND AN ASPECT MAP BY 10 DEGREE SECTORS', MTITLE='ASPECT$MAP',
ASPECT, MAP, TABLE, COMMENT='NOW COMPASS POINT ASPECT', C ASPECT, TABLE,
MAP, GMAP, COMMENT='AND RELATIVE ASPECT', R ASPECT=180., TABLE, MAP, GMAP,
COMMENT='CHECK CELLS WHICH DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS BY MORE THAN 150 FEET.', MTITLE='DATA CHECK$MAP', D CHECK=150., MAP, GMAP, TABLE,
COMMENT='NOTICE THAT THERE IS ONE ESPECIALLY BAD CELL AT (17,36)',
COMMENT='ITS NEIGHBORS APPEAR IN ERROR ALSO BECAUSE THIS ONE CELL ALTERS THE AVERAGE FOR THOSE CELLS.',
COMMENT='PRINT THE ACTUAL ELEVATION DATA',MESSAGE='ELEVATION$MAP', @PRINT,
XOBS=22, YOBS=18,COMMENT='THIS IS AN ALTERNATIVE WAY TO SET OBSERVER POSITION',
COMMENT='DEMONSTRATE WEIGHTED VIEW OPTIONS',MTITLE='WEIGHTED$MAP',
ANON, VIEW, MAP, TABLE, AWOFF, COMMENT='DEFINE DISTANCE WEIGHTING FUNCTION',
NO DWTP, T POINT=(0.5, 1.), TPOINT=(1.0, 0.5), CLEAR, D W ON, VIEW, MAP, TABLE,
CLEAR,COMMENT='NOW BOTH WEIGHTING METHODS',A W ON,VIEW,MAP,A W OFF, D W OFF,
COMMENT='DEFINE SOME SLOPE CLASSES.',
CLASS(1)=(0,25.), CLASS(2)=(25,50.),CLASS(3)=(50,1000.), N CLASS=3,
COMMENT='FOR SLOPE, CLASSES ARE TAKEN AS SLOPES IN PERCENT',
MTITLE='USER$SLOPE$MAP',
U SLOPE, TABLE, MAP,
COMMENT='NOW CALCULATE SLOPE BY THE MAXIMUM SLOPE METHOD', U X SLOPE,
TABLE, MAP,
MTITLE='ELEVATION$CLASS MAP',
COMMENT='DEFINE SOME ELEVATION CLASSES', CLASS(1)=(0,4000), CLASS(2)=(4000,5000)
, CLASS(3)=(5000,6000), CLASS(4)=(6000,7000), CLASS(5)=(7000, 10000), NCLASS=
5, U ELEV, TABLE, MAP,
COMMENT='DEFINE ASPECT SECTORS AND ANALYZE ASPECT BY THEM',
CLASS(1)=(360., 360.), CLASS(2)=(0, 10), NCLASS=2,
COMMENT='ASPECTS OUTSIDE THE DEFINED CLASSES WILL BE PUT IN CLASS ZERO',
MTITLE='USER$ASPECT$S',
U ASPECT, TABLE, MAP,
COMMENT='END OF DEMONSTRATION OF VIEWIT.', STOP,
@FIN

```


@HDG ***DEMONSTRATION RUN***

@MSG,N DATA INPUT IS FROM CARDS:

@MSG,T ZDATA, . CREATE A TEMPORARY FILE, 'ZDATA,'

@DATA,I ZDATA, . INSERT DATA CARD IMAGES INTO FILE 'ZDATA,'
DATA T7 RL70-S 05/12-11:45:33
END DATA, IMAGE COUNT: 52

@XQT PSW*VIEWIT, . NOW RUN THE VIEWIT SYSTEM

V I E W I T

GENERAL VISIBILITY PROGRAM

FOREST RECREATION AND LANDSCAPE MANAGEMENT PROJECT
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. FOREST SERVICE, BERKELEY, CALIFORNIA

RUN ON 05/13/75 AT 09:30:25

== INPUT CARD: COMMENT='FIRST DEFINE AND READ THE DATA',

USER REQUEST: COMME =
FIRST DEFINE AND READ THE DATA

== INPUT CARD: NROWS=52, NCOLS=36, ZSCALE=100., FORMAT='(36F2,0)', COL DOWN, READ,

USER REQUEST: NROWS = 52
NROWS SET TO 52
USER REQUEST: NCOLS = 36
NCOLS SET TO 36
USER REQUEST: ZSCALE = 100
ZSCALE SET TO 100.00000
USER REQUEST: FORMAT =
(36F2,0)
DATA FORMAT WILL BE:
(36F2,0)

USER REQUEST: COLDOW
COLUMNS APPEAR ON THE DATA MEDIUM FROM TOP TO BOTTOM.
USER REQUEST: READ
DATA HAS BEEN READ INTO 1872 ADDITIONAL DBANK LOCATIONS

SOME PROPERTIES OF THE DATA REGION ARE:

EACH CELL IS .20 INCHES (.51 CM.) WIDE AND
.17 INCHES (.42 CM.) HIGH ON THE MAP.

THIS CORRESPONDS TO A CELL 400.00 FEET (121.92 METERS) IN ITS EAST-WEST DIMENSION AND
333.33 FEET (101.60 METERS) IN ITS NORTH-SOUTH DIMENSION ON THE GROUND.

EACH CELL HAS AN AREA OF .0048 SQUARE MILES (3.06 ACRES, 7.56 HECTARES) ON THE GROUND.

THE DATA REGION IS 7.20 INCHES (18.29 CM.) WIDE
AND 8.67 INCHES (22.01 CM.) HIGH ON THE MAP.

THIS CORRESPONDS TO A REGION 2.73 MILES (4.39 KM.) EAST TO WEST AND
3.28 MILES (5.28 KM.) NORTH TO SOUTH ON THE GROUND.

THE AREA OF THE REGION IS 8.95 SQUARE MILES
(5730.03 ACRES, 14159.14 HECTARES) ON THE GROUND.

```

== INPUT CARD; COMMENT='NOTE USE OF ZSCALE TO BRING THE DATA TO THE RIGHT RANGE',

  USER REQUEST; COMMENT =
NOTE USE OF ZSCALE TO BRING THE DATA TO THE RIGHT RANGE

== INPUT CARD; COMMENT='DEFAULTS SUCH AS ROW RIGHT, BCD, MSIZE=24000 HAVE BEEN USED.',

  USER REQUEST; COMMENT =
DEFAULTS SUCH AS ROW RIGHT, BCD, MSIZE=24000 HAVE BEEN USED.

== INPUT CARD; COMMENT='NOW DEFINE AN OBSERVER POINT AND DO A VISIBILITY ANALYSIS',

  USER REQUEST; COMMENT =
NOW DEFINE AN OBSERVER POINT AND DO A VISIBILITY ANALYSIS

== INPUT CARD; MTITLE='SEEN AREA$MAP',

  USER REQUEST; MTITLE =
SEEN AREA MAP
MAP TITLE IS: SEEN AREA
MAP

== INPUT CARD; OBS=(22,18),RADIUS=1.5, VIEW, COMMENT='NOW PRINT A NUMERIC MAP',

  USER REQUEST; OBS = ( 22.00, 18.00)
X OBS SET TO 22 AND Y OBS SET TO 18
  USER REQUEST; RADIUS = 1.50
RADIUS SET TO 1.50000
  USER REQUEST; VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:
=====
X OBS 22
Y OBS 18
RADIUS 1.500 (MILES)
2.414 (KILOMETERS)
DELTA X .20
DELTA Y .17
SCALE 24000.00
XMIN 1
XMAX 36
YMIN 1
YMAX 52
ZANGLE -90.00
ZBIAS 0
SECTORS 0

ANALYSIS COMPLETE,
THIS OBSERVER CAN SEE 184 CELLS ( .88 SQUARE MILES,
563.21 ACRES, 1391.71 HECTARES,)

  USER REQUEST; COMMENT =
NOW PRINT A NUMERIC MAP

== INPUT CARD; MAP, COMMENT='AND A GREY SCALE MAP', MTITLE='',

  USER REQUEST; MAP

MAP OF TIMES SEEN FOR EACH CELL.
1 OBSERVER(S)

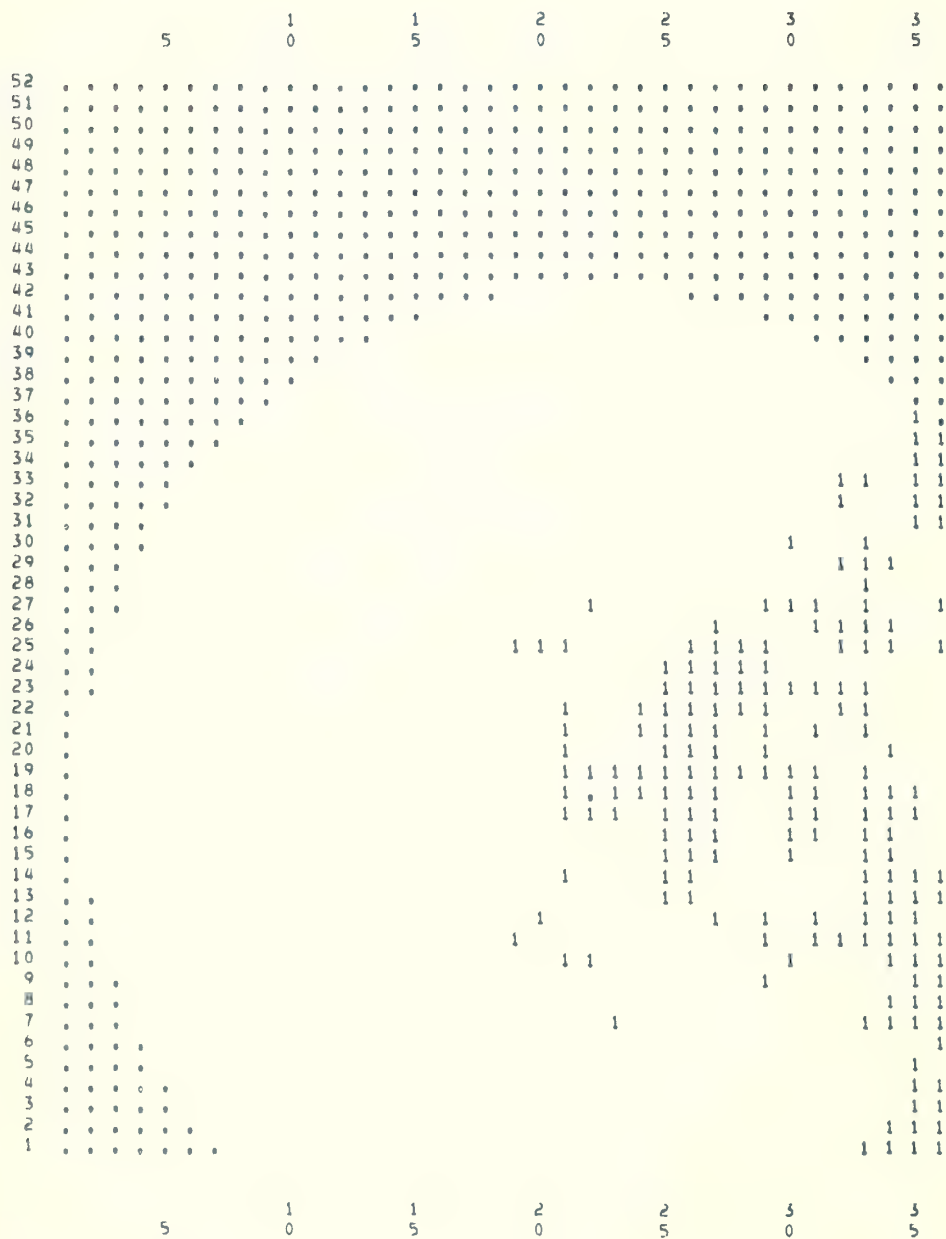
. MARKS UNOBSERVED CELLS
INVISIBLE CELLS ARE BLANK

```

SEEN

AREA

MAP



USER REQUEST; COMMEN =
AND A GREY SCALE MAP
USER REQUEST; GMAP

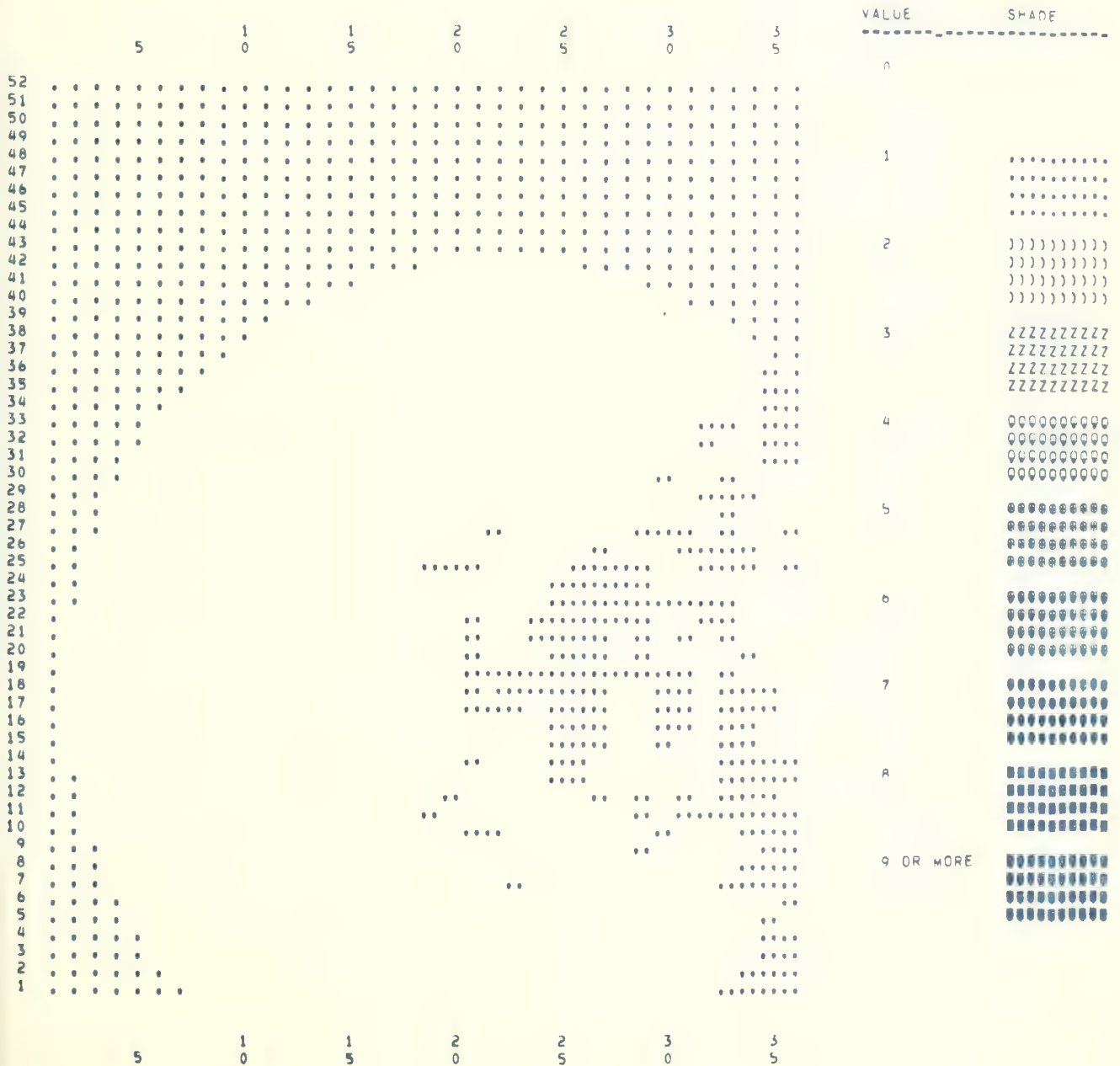
GREY

SCALE

GREEN

AREA

MAP



== INPUT CARD: COMMENT='ADD A SECOND OBSERVER',OBS=(20,20),VIEW,

USER REQUEST: COMMENT =
ADD A SECOND OBSERVER
USER REQUEST: OBS = (20.00, 20.00)
X OBS SET TO 20 AND Y OBS SET TO 20
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

```
=====
X OBS      20
Y OBS      20
RADIUS      1.500 (MILES)
           2.414 (KILOMETERS)
DELTA X     .20
DELTA Y     .17
SCALE      24000.00
XMIN        1
XMAX        36
YMIN        1
YMAX        52
ZANGLE      -90.00
ZBIAS       0
SECTORS     0
=====
```

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 307 CELLS (1.47 SQUARE MILES,
939.70 ACRES, 2322.04 HECTARES.)

== INPUT CARD: MTITLE='TIMES SEEN\$MAP',MAP,

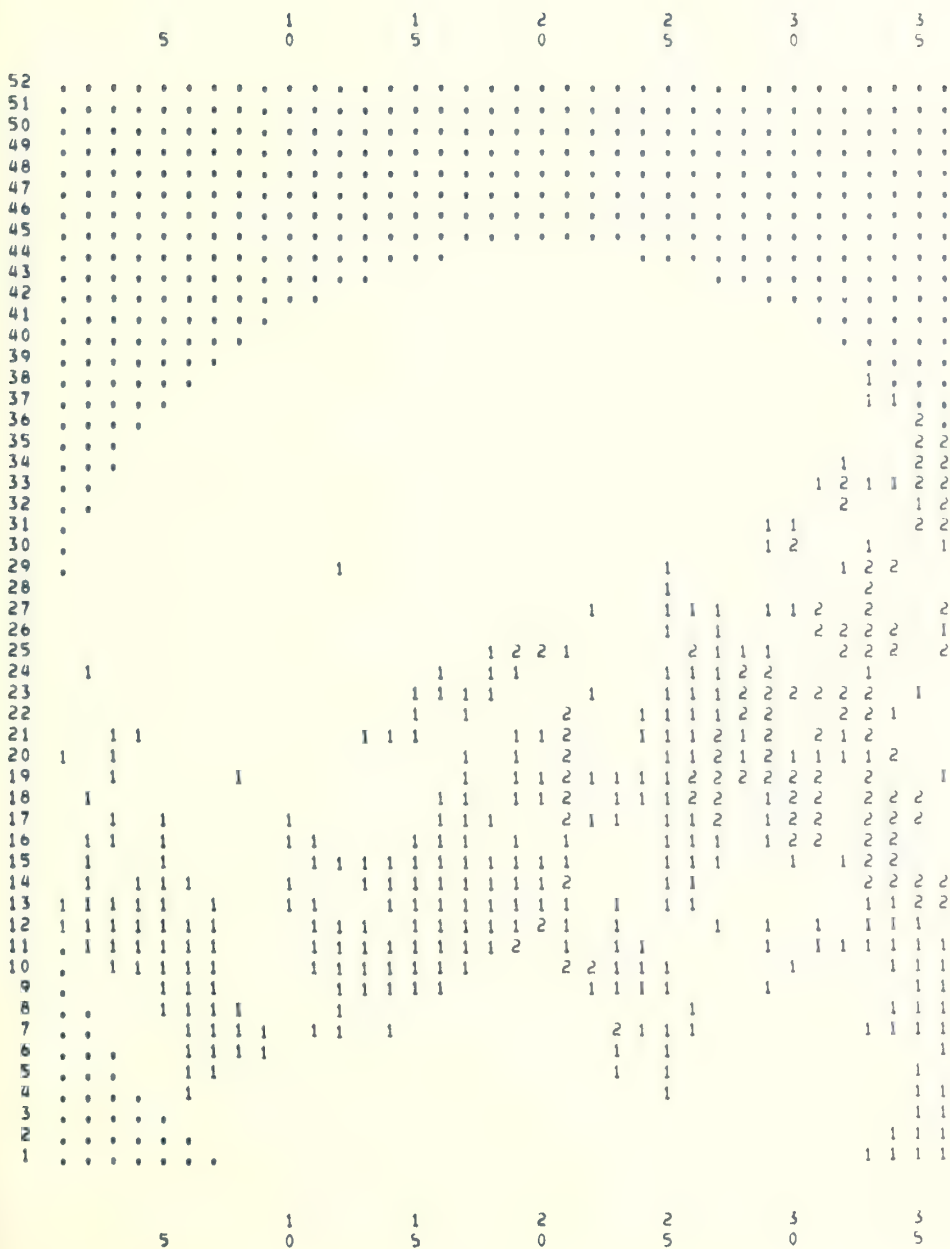
USER REQUEST: MTITLE =
TIMES SEEN MAP
MAP TITLE IS: TIMES SEEN
MAP
USER REQUEST: MAP

MAP OF TIMES SEEN FOR EACH CELL.
2 OBSERVER(S)

. MARKS UNOBSERVED CELLS
INVISIBLE CELLS ARE BLANK

THESEEN

MAP



== INPUT CARD: COMMENTS='NOW WITH THE AVERAGE MAP OPTION INSTEAD.',

USER REQUEST: COMMEN =
NOW WITH THE AVERAGE MAP OPTION INSTEAD.

== INPUT CARD: AVG MAP, MTITLE='AVERAGE MAP\$TIMES SEEN', MAP, MTITLE='',

USER REQUEST: AVGMAP
VISIBILITY MAPS WILL PRINT TIMES SEEN AS A PERCENT
OF THE NUMBER OF OBSERVERS.

USER REQUEST: MTITLE =

AVERAGE MAP TIMES SEEN

MAP TITLE IS: AVERAGE MAP

TIMES SEEN

USER REQUEST: MAP

MAP OF TIMES SEEN FOR EACH CELL.
2 OBSERVER(S)

. MARKS UNOBSERVED CELLS
INVISIBLE CELLS ARE BLANK

TIMES SEEN IS DISPLAYED AS A PERCENT OF THE NUMBER OF OBSERVERS.

LESS THAN 10% BLANK

10% TO 20% 1

20% TO 30% 2

100% 10 (SEEN BY ALL OBSERVERS)

AVERAGE MAP

TILES SEEN

	5	1 0	1 5	2 0	2 5	3 0	3 5
52	.	.	.	.	.	.	.
51	.	.	.	.	.	.	.
50	.	.	.	.	.	.	.
49	.	.	.	.	.	.	.
48	.	.	.	.	.	.	.
47	.	.	.	.	.	.	.
46	.	.	.	.	.	.	.
45	.	.	.	.	.	.	.
44	.	.	.	.	.	.	.
43	.	.	.	.	.	.	.
42	.	.	.	.	.	.	.
41	.	.	.	.	.	.	.
40	.	.	.	.	.	.	.
39	.	.	.	.	.	.	.
38	.	.	.	.	.	.	.
37	.	.	.	.	.	.	.
36	.	.	.	.	.	.	.
35	.	.	.	.	.	.	.
34	.	.	.	.	.	.	.
33	.	.	.	.	.	.	.
32	.	.	.	.	.	.	.
31	.	.	.	.	.	.	.
30	.	.	.	.	.	.	.
29	.	.	.	.	.	.	.
28	.	.	.	.	.	.	.
27	.	.	.	.	.	.	.
26	.	.	.	.	.	.	.
25	.	.	.	.	.	.	.
24	.	.	.	.	.	.	.
23	.	.	.	.	.	.	.
22	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.
20	.	.	.	.	.	.	.
19	.	.	.	.	.	.	.
18	.	.	.	.	.	.	.
17	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.
1	.	.	.	.	.	.	.

USER REQUEST: GMAP

MAP OF TIMES SEEN FOR EACH CELL.
2 OBSERVER(S)

. MARKS UNOBSERVED CELLS
INVISIBLE CELLS ARE BLANK

TIMES SEEN IS DISPLAYED AS A PERCENT OF THE NUMBER OF OBSERVERS.

LESS THAN 10% BLANK

10% TO 20% 1

20% TO 30% 2

100% 10 (SEEN BY ALL OBSERVERS)

GREY SCALE EXPLANATION:

VALUE	SHADE
0	
1	
2	)))))))))
3	ZZZZZZZZZZ
4	0000000000
5	0000000000
6	0000000000
7	0000000000
8	0000000000
9 OR MORE	0000000000

GRAY SCALE

TIMES SEEN

AVERAGE MAP

5 10 15 20 25 30 35



5 10 15 20 25 30 35

USER REQUEST: NUMMAP
VISIBILITY MAPS WILL PRINT TIMES SEEN AS A NUMBER.

== INPUT CARD: COMMENT='NUM MAP COMMAND SET MAP MODE BACK TO THE DEFAULT OF NUMERIC MAPS OF TIME'

== INPUT CARD: ES SEEN', COMMENT= 'CLEAR COUNT FIELD AND DO A NEW SET OF VISIBILITY ANALYSES.'

USER REQUEST: COMMENT =
NUM MAP COMMAND SET MAP MODE BACK TO THE DEFAULT OF NUMERIC MAPS OF TIMES SEEN

USER REQUEST: COMMENT =
CLEAR COUNT FIELD AND DO A NEW SET OF VISIBILITY ANALYSES.

== INPUT CARD: , M TITLE='SUBRECTANGLE', CLEAR, X MIN= 10, YMIN=10, YMAX=30,

USER REQUEST: MTITLE =
SUBRECTANGLE
MAP TITLE Is: SUBRECTANGLE

USER REQUEST: CLEAR
COUNT FIELD CLEARED FOR CELLS IN THE CURRENT SUBRECTANGLE

USER REQUEST: XMIN = 10
XMIN SET TO 10
USER REQUEST: YMIN = 10
YMIN SET TO 10
USER REQUEST: YMAX = 30
YMAX SET TO 30

== INPUT CARD: COMMENT='NOW ALL OPTIONS AFFECT ONLY THIS SUBRECTANGLE.', VIEW, MAP, TABLE,

USER REQUEST: COMMENT =
NOW ALL OPTIONS AFFECT ONLY THIS SUBRECTANGLE.
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

=====

X ORS	20	
Y ORS	20	
RADTUS	1.500	(MILES)
	2.414	(KILOMETERS)
DELTA X	.20	
DELTA Y	.17	
SCALE	24000.00	
XMIN	10	
XMAX	36	
YMIN	10	
YMAX	30	
ZANGLE	-90.00	
ZBIAS	0	
SECTORS	0	

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 203 CELLS (.97 SQUARE MILES,
621.36 ACRES, 1535.42 HECTARES.)

USER REQUEST: MAP

MAP OF TIMES SEEN FOR EACH CELL.
1 OBSERVER(S)

. MARKS UNOBSERVED CELLS
INVISIBLE CELLS ARE BLANK

COUNT FIELD CLEARED FOR CELLS IN THE CURRENT SUBRECTANGLE

```

USER REQUEST: COMEN =
RESET TO SCAN THE WHOLE CIRCLE
USER REQUEST: NSECT
NO AZIMUTH SECTORS.

```

```

** INPUT CARD: COMMENT='PRINT A CROSS-SECTIONAL PROFILE', END=(37,52), PROFILE,

```

```

      USEW REQUEST; COMEN =
      PRINT A CROSS-SECTIONAL PROFILE
      USEW REQUEST; END * ( 37.00, 52.00)
      X END SET TO 36 AND Y END SET TO 52
      USEW REQUEST; PROFILE

```

ELEVATION PROFILE FROM POINT (20, 20) TO POINT (36, 52).

(POINTS MARKED & ARE VISIBLE FROM THE FIRST POINT)

[illegible]

SECTOR

MAP



== INPUT CARD: COMMENT='EXAMINE ONLY CERTAIN AZIMUTH SECTORS FOR VISIBILITY',

USER REQUEST: COMMENT =
EXAMINE ONLY CERTAIN AZIMUTH SECTORS FOR VISIBILITY

== INPUT CARD: CLEAR, MTITLE='SECTOR\$MAP', SECTOR=(90,180), SECTOR=(225,315,), VIEW,

USER REQUEST: CLEAR

COUNT FIELD CLEARED FOR CELLS IN THE CURRENT SUBRECTANGLE

USER REQUEST: MTITLE =
SECTOR MAP
MAP TITLE IS: SECTOR
MAP

USER REQUEST: SECTOR = (90.00, 180.00)
AZIMUTH SECTOR 1 IS FROM, 90.00 DEGREES TO 180.00 DEGREES.
USER REQUEST: SECTOR = (225.00, 315.00)
AZIMUTH SECTOR 2 IS FROM, 225.00 DEGREES TO 315.00 DEGREES.
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

=====

X ORS	20
Y ORS	20
RADIUS	1.500 (MILES)
	2.414 (KILOMETERS)
DELTA X	.20
DELTA Y	.17
SCALE	24000.00
XMIN	1
XMAX	36
YMIN	1
YMAX	52
ZANGLE	-90.00
ZBIAS	0
SECTORS	2
SECTOR 1	(90.00, 180.00)
SECTOR 2	(225.00, 315.00)

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 187 CELLS (.89 SQUARE MILES,
572.39 ACRES, 1414.40 HECTARES.)

== INPUT CARD: MAP, CLEAR, COMMENT='RESET TO SCAN THE WHOLE CIRCLE', N SECT,

USER REQUEST: MAP

SUBRECTANGLE

	1 0	1 5	2 0	2 5	3 0	3 5
30					1 1	1
29	1			1		1 1
28				1		1
27				1 1 1	1	1
26				1	1 1 1	1
25			1 1 1		1 1 1	1
24		1	1 1	1	1 1	1
23		1 1 1	1		1 1 1 1 1 1	1
22		1	1		1 1	1 1 1
21	1 1 1		1 1 1		1 1 1 1 1 1	
20			1	1 1 1 1 1 1	1 1 1	
19			1	1 1 1 1 1	1	1
18			1 1	1 1 1 1 1 1 1 1 1	1 1 1	
17	1		1 1 1	1	1 1 1	1 1 1
16	1 1		1 1 1		1 1 1	1 1
15	1	1 1 1 1 1 1 1 1 1			1 1 1	
14	1	1 1 1 1 1 1 1 1 1			1 1 1 1	
13	1 1	1 1 1 1 1 1 1 1 1	1			1 1
12	1 1 1	1 1 1 1 1 1 1	1			
11	1 1 1 1 1 1 1 1 1	1	1 1 1			
10	1 1 1 1 1 1 1	1 1 1 1 1	1 1 1 1 1			
	1 0	1 5	2 0	2 5	3 0	3 5

USER REQUEST: TABLE

TABLE OF NUMBERS OF CELLS AND AREAS SEEN BY 1 OBSERVER(S).

TIMES SEEN	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	364	1.74	1114.17	2753.17
1	203	.97	621.36	1535.42

== INPUT CARD: COMMENT='NOW GO BACK TO THE WHOLE DATA GRID', XMIN=1, YMIN=1, XMAX=36, YMAX=52,

```

USER REQUEST: COMMENT =
NOW GO BACK TO THE WHOLE DATA GRID
USER REQUEST: XMIN      =      1
XMIN  SET YO           =      1
USER REQUEST: YMIN      =      1
YMIN  SET YO           =      1
USER REQUEST: XMAX      =     36
XMAX  SET YO           =     36
USER REQUEST: YMAX      =     52
YMAX  SET YO           =     52

```


== INPUT CARD: MTITLE='SLOPESMAP', COMMENT='PRINT A SLOPE CLASS MAP', SLOPE, TABLE, MAP, MAP,

USER REQUEST: MTITLE =
 SLOPE MAP
 MAP TITLE IS: SLOPE
 MAP
 USER REQUEST: COMMENT =
 PRINT A SLOPE CLASS MAP
 USER REQUEST: SLOPE

SLOPE CLASS VALUES CALCULATED FOR CURRENT SUBRECTANGLE.

USER REQUEST: TABLE

SLOPE CLASS TABLE,
 0 MEANS 0 TO 10% SLOPE,
 1 MEANS 10 TO 20% SLOPE,
 2 MEANS 20 TO 30% SLOPE, ETC.

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	452	2.16	1383.53	3419.77
1	592	2.83	1812.06	4477.66
2	466	2.23	1426.36	3524.66
3	230	1.10	704.01	1757.64
4	94	.45	287.73	710.46
5	23	.11	70.40	173.46
6	7	.03	21.43	52.95
14	1	.00	3.06	7.56
17	2	.01	6.12	15.13
22	1	.00	3.06	7.56
24	2	.01	6.12	15.13
29	2	.01	6.12	15.13

USER REQUEST: MAP

SLOPE CLASS MAP,
 BLANK MEANS 0 TO 10% SLOPE,
 1 MEANS 10 TO 20% SLOPE,
 2 MEANS 20 TO 30% SLOPE, ETC.

505

505

	5	0	5	0	5	0	5
52	1	1	1	1		1	1
51	3	3	2	1	1	1	1
50			1		1	1	1
49	3	3	1		1	1	1
48	1	1	1	1	1	1	1
47			1	1	1	1	1
46				1	1	1	1
45				1	1	1	1
44	1	1	1		1	1	1
43	1	2	3	3	1		
42		2	2	3	2	1	
41	1	2	2	2	2	2	1
40	1	2	1	2	3	3	3
39		1	1				
38							
37	1	1	1	2	3	3	3
36	1	1	2	2	2	2	2
35	2	1	2	2	1	1	1
34	2	1	4	2	1	1	1
33	2	3	4	2	1	2	2
32	3	3	2	1	2	2	2
31	1	2	2	1	2	3	3
30	1	3	2	2	2	3	3
29	1	2	3	2	1	1	3
28	1	2	1	1	2	2	4
27	1	3	2	2	2	2	3
26	1	2	1	1	2	2	2
25	2	2	1	1	2	2	1
24	1	2		1	1	2	1
23	1	2	1		1	1	2
22		2	1		1	1	2
21		2	1		1	1	2
20	1	2	1	1	1	1	1
19	1	1	1	1	1	1	1
18	1	2	1		1	1	1
17	1	2	3	2	1	1	2
16	3	3	2	3	2	1	1
15	4	3	2	2	2	1	1
14	4	3	2	1	1	1	2
13	3	3	2	1	1	1	2
12	1	1	2	2	2	2	2
11		1	2	2	2	2	2
10	2	2	1	2	3	2	3
9	3	3	2	3	3	3	3
8	2	2	2	4	3	4	4
7	2	3	3	5	2	3	4
6	2	4	3	4	4	1	1
5	2	4	4	5	4	1	2
4	2	4	4	5	3	1	3
3	2	3	3	4	2	1	2
2	2	4	4	3	1	1	2
1	2	4	4	2		1	2

USER REQUEST: GMAP

SLOPE CLASS MAP,
BLANK MEANS 0 TO 10% SLOPE,
1 MEANS 10 TO 20% SLOPE,
2 MEANS 20 TO 30% SLOPE, ETC.

SLOPE

MAP



== INPUT CARD: COMMENT='FIND SLOPE CLASSES BY THE MAXIMUM SLOPE METHOD RATHER THAN THE

== INPUT CARD: AVERAGING METHOD USED BEFORE', X SLOPE, TABLE,

USER REQUEST: COMMENT =
FIND SLOPE CLASSES BY THE MAXIMUM SLOPE METHOD RATHER THAN THE
USER REQUEST: XSLOPE

AVERAGING METHOD USED BEFORE

MAXIMUM SLOPE CLASS VALUES COMPUTED FOR CURRENT SUBRECTANGLE.

USER REQUEST: TABLE

TABLE OF MAXIMUM SLOPE CLASSES.
0 MEANS 0 TO 10% SLOPE
1 MEANS 10% TO 20% SLOPE, ETC.

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	227	1.09	694.83	1716.95
1	77	.37	235.69	582.40
2	208	.99	636.67	1573.24
3	853	4.08	2610.96	6451.79
5	284	1.36	869.30	2148.08
6	181	.87	554.02	1369.02
7	14	.07	42.85	105.89
9	9	.04	27.55	68.07
10	1	.00	3.06	7.56
15	1	.00	3.06	7.56
17	2	.01	6.12	15.13
19	1	.00	3.06	7.56
22	1	.00	3.06	7.56
24	1	.00	3.06	7.56
25	1	.00	3.06	7.56
27	2	.01	6.12	15.13
72	1	.00	3.06	7.56
74	1	.00	3.06	7.56
80	2	.01	6.12	15.13
89 OR MORE	5	.02	15.30	37.82

== INPUT CARD: MTITLE='MAXIMUMSLOPE MAP', MAP, GMAP,

USER REQUEST: MTITLE =
MAXIMUM SLOPE MAP
MAP TITLE IS: MAXIMUM
SLOPE MAP
USER REQUEST: MAP

MAP OF MAXIMUM SLOPE CLASSES
BLANK MEANS 0 TO 10% SLOPE
1 MEANS 10% TO 20%, ETC.

MAP OF MAXIMUM SLOPE CLASSES
BLANK MEANS 0 TO 10% SLOPE
1 MEANS 10% TO 20%, ETC.



	1	1	2	2	3	3
5	0	5	0	5	0	5

[illegible]

	1	1	2	2	3	4
5	0	5	0	5	0	5

USER REQUEST: TABLE

ASPECT CLASS TABLE,

36 ASPECT CLASSES,

1 MEANS 0 TO 10 DEGREES,

2 MEANS 10 TO 20 DEGREES,

ETC.

ZERO CELLS HAVE NO ASPECT (ARE FLAT).

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	237	1.13	725.44	1792.58
1	107	.51	327.52	809.31
2	43	.21	131.62	325.24
3	51	.24	156.11	385.75
4	79	.38	241.81	597.53
5	20	.10	61.22	151.27
6	56	.27	171.41	423.56
7	21	.10	64.28	158.84
8	38	.18	116.31	287.42
9	78	.37	238.75	589.96
10	12	.06	36.73	90.76
11	37	.18	113.25	279.85
12	25	.12	76.52	189.09
13	46	.22	140.80	347.93
14	13	.06	39.79	98.33
15	63	.30	192.84	476.51
16	34	.16	104.07	257.16
17	17	.08	52.04	128.58
18	65	.31	198.96	491.64
19	7	.03	21.43	52.95
20	25	.12	76.52	189.09
21	35	.17	107.13	264.73
22	70	.33	214.26	529.46
23	23	.11	70.40	173.96
24	60	.29	183.65	453.82
25	39	.19	119.38	294.98
26	47	.22	143.86	355.49
27	14	.07	42.85	105.89
28	128	.61	391.80	968.15
29	41	.20	125.50	310.11
30	37	.18	113.25	279.85
31	64	.31	195.90	484.07
32	21	.10	64.28	158.84
33	79	.38	241.81	597.53
34	57	.27	174.47	431.13
35	60	.29	183.65	453.82
36	23	.11	70.40	173.96

USER REQUEST: COMMEN =
 NOW COMPASS POINT ASPECT
 USER REQUEST: CASPEC

ASPECT CLASSES BY PRINCIPAL COMPASS DIRECTIONS CALCULATED
 FOR THE CURRENT SUBRECTANGLE.

USER REQUEST: TABLE

TABLE OF ASPECTS BY PRINCIPAL COMPASS DIRECTIONS.
 THERE ARE 8 ASPECT CLASSES, EACH REPRESENTS A 45 DEGREE
 WIDE RANGE CENTERED ON A COMPASS POINT:

1	+-22.5 DEG. FROM NORTH
2	+-22.5 DEG. FROM NE
3	+-22.5 DEG. FROM EAST
4	+-22.5 DEG. FROM SE
5	+-22.5 DEG. FROM SOUTH
6	+-22.5 DEG. FROM SW
7	+-22.5 DEG. FROM WEST
8	+-22.5 DEG. FROM NW
ZERO	NO ASPECT (FLAT)

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	237	1.13	725.44	1792.58
1	234	1.12	716.25	1764.89
2	216	1.03	661.16	1635.75
3	190	.91	581.57	1437.69
4	166	.79	508.11	1255.57
5	114	.55	348.94	862.26
6	205	.98	627.49	1567.55
7	266	1.27	814.20	2011.43
8	244	1.17	746.86	1845.53

== INPUT CARD: MAP, GMAP, COMMENT='LAND RELATIVE ASPECT', R ASPECT=180., TABLE, MAP, GMAP,

USER REQUEST: MAP

MAP OF ASPECT BY PRINCIPAL COMPASS DIRECTIONS.
 THERE ARE 8 ASPECT CLASSES, EACH REPRESENTS A 45 DEGREE
 WIDE RANGE CENTERED ON A COMPASS POINT:

1	+-22.5 DEG. FROM NORTH
2	+-22.5 DEG. FROM NE
3	+-22.5 DEG. FROM EAST
4	+-22.5 DEG. FROM SE
5	+-22.5 DEG. FROM SOUTH
6	+-22.5 DEG. FROM SW
7	+-22.5 DEG. FROM WEST
8	+-22.5 DEG. FROM NW
BLANK	NO ASPECT (FLAT)



	5					1 0	1 5	2 0	2 5	3 0	3 5				
52	1	1	1	2	2					6	7	7	7	7	8
51	1	1	2	2	2	2	2			7	7	7	8	8	8
50			3	3	3	2	2			7	7	8	8	8	8
49	5	5	4	5	8	2	3			7	8	8	8	7	6
48	5	5	5	6	6	5	4			8	8	8	8	6	8
47			6	6	5	5	4			8	8	8	8	6	8
46						5	4			7	7	6	5	7	8
45	8	1	2	2						7	7	6	5	7	6
44	1	1	1	1						7	7	6	5	7	6
43	8	8	2	2						8	8	7	5	8	8
42	8	8	1	2	2	1	2			8	8	7	6	8	8
41	7	7	3	2	1	1	2	1		2	7	7	7	6	4
40	7	7	7	3	1	1	2	2		2	7	7	6	5	4
39	8	7	6	3	1	8	2	8		1	2	8	7	6	4
38	2	7	7	8	8	1	2	1	1	1	3	4	7	6	5
37	4	5	7	8	8	1	2	1	1	2	2	3	6	5	6
36	4	5	6	6	7	6	4	3	1	2	3	2	5	6	8
35	4	5	7	7	7	6	6	2	1	3	3	2	2	7	8
34	5	6	7	8	7	7	8	8	1	4	4	2	2	7	7
33	5	7	7	7	6	7	7	8	1	4	4	2	2	7	6
32	8	7	7	6	6	7	7	7	1	3	4	2	2	6	5
31	8	7	7	7	7	6	6	6	1	3	4	3	3	1	7
30	6	7	7	6	6	5	6	6	2	3	4	3	2	8	2
29	6	6	6	6	6	7	7	8	1	2	3	4	6	8	2
28	7	7	7	8	8	8	8	7	1	2	3	4	5	6	3
27	7	7	8	8	8	8	7	7	2	2	3	4	3	8	7
26	8	7	7	7	7	6	5	4	2	3	3	4	2	1	8
25	8	8	8	7	7	6	7	7	3	4	4	5	4	3	3
24	7	7	8	7	7	7	7	5	4	4	5	4	4	1	1
23	6	7	6	8	7	6	6	5	5	3	3	4	3	1	2
22	7	7	7	6	7	6	6	5	5	3	3	3	2	8	2
21	7	7	6	6	6	6	6	6	7	3	3	3	2	1	8
20	6	6	6	6	6	6	7	8	8	2	1	8	1	1	1
19	6	6	7	6	5	6	7	6	6	3	3	2	1	1	1
18	7	7	7	7	7	6	5	6	6	3	3	2	1	1	2
17	7	8	8	1	1	8	7	7	6	3	3	2	1	8	2
16	8	8	8	8	1	2	8	8	7	3	3	3	4	3	6
15	8	8	8	8	2	2	8	8	7	4	4	4	4	6	7
14	1	1	1	8	2	2	1	8	8	2	2	3	4	4	4
13	1	1	8	1	2	1	1	7	8	1	8	8	6	6	6
12	1	1	8	1	2	1	1	2	7	8	1	8	2	2	3
11	5	8	8	1	1	1	2	7	7	8	1	1	8	6	5
10	5	6	7	8	1	1	2	8	7	7	8	8	4	4	4
9	6	6	6	7	8	1	2	1	8	7	8	8	1	1	6
8	6	6	7	7	8	1	1	1	8	8	8	8	4	5	4
7	7	7	7	8	8	2	1	1	8	7	4	3	4	5	5
6	6	7	7	7	7	2	1	1	8	7	4	3	3	4	5
5	7	7	7	7	7	6	4	3	4	5	6	6	5	4	4
4	8	7	7	7	7	5	4	4	5	6	6	5	4	4	4
3	8	7	7	7	7	4	4	4	4	4	4	4	4	3	3
2	8	8	8	7	7	4	4	4	4	5	4	4	3	3	8
1	7	7	7	7	7	4	4	4	4	5	4	4	3	1	1

ASPECT

MAP

5 1 1 2 2 3 3
0 0 5 0 5 0 5

```

52 .....)))
51 .....)))
50 ZZZ.....)))
49 .....)))ZZZ
48 .....ZZZZZZ
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46 .....
45 .....
44 .....
43 .....)))
42 .....)))
41 .....ZZ.....)))
40 .....ZZ.....)))
39 .....ZZ.....)))
38 .....ZZ.....)))
37 .....ZZ.....)))
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34 .....ZZ.....)))
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8 .....ZZ.....)))
7 .....ZZ.....)))
6 .....ZZ.....)))
5 .....ZZ.....)))
4 .....ZZ.....)))
3 .....ZZ.....)))
2 .....ZZ.....)))
1 .....ZZ.....)))

```

5 1 1 2 2 3 3
0 0 5 0 5 0 5

USER REQUEST: COMMEN =
 AND RELATIVE ASPECT
 USER REQUEST: RASPEC = 180

ASPECT CLASSES CALCULATED RELATIVE TO THE USER-SPECIFIED DIRECTION OF 180.0 DEGREES

USER REQUEST: TABLE

TABLE OF ASPECTS RELATIVE TO USER-SPECIFIED DIRECTION
 THERE ARE 8 CLASSES, EACH REPRESENTING ANGLES IN TWO 22.5
 DEGREE BANDS, ONE ON EACH SIDE OF THE SPECIFIED DIRECTION;
 1 +-0, TO 22.5 DEG. RELATIVE TO THE GIVEN ANGLE
 2 +-22.5 TO 45 DEG
 3 +-45 TO 67.5 DEG
 4 +-67.5 TO 90. DEG
 5 +-90. TO 112.5 DEG
 6 +-112.5 TO 135. DEG
 7 +-135. TO 157.5 DEG
 8 +-157.5 TO 180. DEG
 ZERO NO ASPECT (FLAT)

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	237	1.13	725.44	1792.58
1	114	.55	348.94	862.26
2	202	.97	618.30	1527.86
3	169	.81	517.29	1278.26
4	147	.70	449.95	1111.86
5	309	1.48	945.82	2337.17
6	186	.89	569.33	1406.84
7	274	1.31	838.69	2072.44
8	234	1.12	716.25	1769.89

USER REQUEST: MAP

MAP OF CELL ASPECT RELATIVE TO A USER-SPECIFIED DIRECTION,
 THERE ARE 8 CLASSES, EACH REPRESENTING ANGLES IN TWO 22.5
 DEGREE BANDS, ONE ON EACH SIDE OF THE SPECIFIED DIRECTION;
 1 +-0, TO 22.5 DEG. RELATIVE TO THE GIVEN ANGLE
 2 +-22.5 TO 45 DEG
 3 +-45 TO 67.5 DEG
 4 +-67.5 TO 90. DEG
 5 +-90. TO 112.5 DEG
 6 +-112.5 TO 135. DEG
 7 +-135. TO 157.5 DEG
 8 +-157.5 TO 180. DEG
 BLANK NO ASPECT (FLAT)
 (IF THE GIVEN ANGLE IS THE SUN DIRECTION, THIS IS
 AN APPROXIMATE SUN-ILLUMINATION MAP.)

49

MAP

MAP

	5	10	15	20	25	30	35
52	#####					ZZQQ))	#####
51	#####				#####	#####	#####
50	#####				#####	#####	#####
49	))				#####	#####	#####
48	)))))ZZ				#####	#####	#####
47	)))))ZZ				#####	#####	#####
46	)))))ZZ				#####	#####	#####
45	#####				#####	#####	#####
44	#####				#####	#####	#####
43	#####				#####	#####	#####
42	#####				#####	#####	#####
41	#####				#####	#####	#####
40	#####				#####	#####	#####
39	#####				#####	#####	#####
38	#####				#####	#####	#####
37	#####				#####	#####	#####
36	#####				#####	#####	#####
35	#####				#####	#####	#####
34	#####				#####	#####	#####
33	#####				#####	#####	#####
32	#####				#####	#####	#####
31	#####				#####	#####	#####
30	#####				#####	#####	#####
29	#####				#####	#####	#####
28	#####				#####	#####	#####
27	#####				#####	#####	#####
26	#####				#####	#####	#####
25	#####				#####	#####	#####
24	#####				#####	#####	#####
23	#####				#####	#####	#####
22	#####				#####	#####	#####
21	#####				#####	#####	#####
20	#####				#####	#####	#####
19	#####				#####	#####	#####
18	#####				#####	#####	#####
17	#####				#####	#####	#####
16	#####				#####	#####	#####
15	#####				#####	#####	#####
14	#####				#####	#####	#####
13	#####				#####	#####	#####
12	#####				#####	#####	#####
11	#####				#####	#####	#####
10	#####				#####	#####	#####
9	#####				#####	#####	#####
8	#####				#####	#####	#####
7	#####				#####	#####	#####
6	#####				#####	#####	#####
5	#####				#####	#####	#####
4	#####				#####	#####	#####
3	#####				#####	#####	#####
2	#####				#####	#####	#####
1	#####				#####	#####	#####

5	10	15	20	25	30	35
---	----	----	----	----	----	----

== INPUT CARD: COMMENT='CHECK CELLS WHICH DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS BY MORE THAN

== INPUT CARD: AN 150 FEET.', MTITLE='DATA CHECK MAP', D CHECK=150., MAP, DIFF, LABEL

USER REQUEST: COMMENT =
CHECK CELLS WHICH DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS BY MORE THAN 150 FEET.

USER REQUEST: MTITLE =

DATA CHECK MAP

MAP TITLE IS: DATA CHECK

MAP

USER REQUEST: D CHECK = 150

DATA CHECK COMPLETED, OF 1872 CELLS, 25 DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS

BY MORE THAN 150.0 FEET.

USER REQUEST: MAP

DATA CHECK CLASS MAP.

BLANK CELLS PASS THE TEST.

1 MEANS CELLS DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS

BY AN AMOUNT BETWEEN THE SPECIFIED TOLERANCE AND TWICE

THE TOLERANCE.

2 MEANS THE DIFFERENCE IS 2*TOLERANCE TO 3*TOLERANCE, ETC.

DATA

CHECK

MAP

	5	1 0	1 5	2 0	2 5	3 0	3 5
52							
51							
50							
49							
48							
47							
46							
45							
44							
43							
42							
41							
40							
39							
38							
37	1 1	1	2 3 3				
36			5 2 7 2				
35			3 3 3				
34				1			
33							
32							
31							
30							
29							
28							
27						6 1	
26						1	
25					1		
24							
23							
22							
21							
20							
19							
18		1	1				
17							
16							
15							
14							
13							
12							
11							
10		1	1				
9							
8	1						
7							
6		1					
5	1						
4							
3							
2			1				
1							
	5	1 0	1 5	2 0	2 5	3 0	3 5

USER REQUEST: TABLE

DATA CHECK CLASS TABLE.

0 MEANS CELLS PASS THE TEST.

1 MEANS CELLS DIFFER FROM THE AVERAGE OF THEIR NEIGHBORS

BY AN AMOUNT BETWEEN THE SPECIFIED TOLERANCE AND TWICE

THE TOLERANCE.

2 MEANS THE DIFFERENCE IS 2*TOLERANCE TO 3*TOLERANCE, ETC.

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	1847	8.83	5653.50	13471.55
1	15	.07	45.91	113.45
2	2	.01	6.14	15.13
3	5	.02	15.30	37.72
5	1	.00	3.06	7.58
6	1	.00	3.06	7.58
27	1	.00	3.06	7.58

== INPUT CARD: COMMENT='NOTICE THAT THERE IS ONE ESPECIALLY BAD CELL AT (17,36)',

USER REQUEST: COMMENT =

NOTICE THAT THERE IS ONE ESPECIALLY BAD CELL AT (17,36)

== INPUT CARD: COMMENT='ITS NEIGHBORS APPEAR IN ERROR ALSO BECAUSE THIS ONE CELL ALTERS THE AVE

== INPUT CARD: RAGE FOR THOSE CELLS.',

USER REQUEST: COMMENT =

ITS NEIGHBORS APPEAR IN ERROR ALSO BECAUSE THIS ONE CELL ALTERS THE AVERAGE FOR THOSE CELLS.

== INPUT CARD: COMMENT='PRINT THE ACTUAL ELEVATION DATA',MESSAGE='ELEVATIONSMAP', DPRINT,

USER REQUEST: COMMENT =

PRINT THE ACTUAL ELEVATION DATA

USER REQUEST: MESSAG =

ELEVATION MAP

USER REQUEST: DPRINT

ELEVATION MAP

FIRST SYMBOL GIVES TWO SANDS AND HUNDREDS DIGIT, SECOND NUMBER IS TENS DIGIT.

TABLE OF SYMBOLS

ELEVATION	SYMBOL	ELEVATION	SYMBOL	ELEVATION	SYMBOL	ELEVATION	SYMBOL
100	1	5100	+	10100	Z	15100	#
200	2	5200	2	10200	2	15200	2
300	3	5300	3	10300	3	15300	3
400	4	5400	4	10400	4	15400	4
500	5	5500	5	10500	5	15500	5
600	6	5600	6	10600	6	15600	6
700	7	5700	7	10700	7	15700	7
800	8	5800	8	10800	8	15800	8
900	9	5900	9	10900	9	15900	9
1000	0	6000	0	11000	0	16000	0
1100	A	6100	A	11100	A	16100	A
1200	B	6200	B	11200	B	16200	B
1300	C	6300	C	11300	C	16300	C
1400	D	6400	D	11400	D	16400	D
1500	E	6500	E	11500	E	16500	E
1600	F	6600	F	11600	F	16600	F
1700	G	6700	G	11700	G	16700	G
1800	H	6800	H	11800	H	16800	H
1900	I	6900	I	11900	I	16900	I
2000	J	7000	J	12000	J	17000	J
2100	K	7100	K	12100	K	17100	K
2200	L	7200	L	12200	L	17200	L
2300	M	7300	M	12300	M	17300	M
2400	N	7400	N	12400	N	17400	N
2500	O	7500	O	12500	O	17500	O
2600	P	7600	P	12600	P	17600	P
2700	Q	7700	Q	12700	Q	17700	Q
2800	R	7800	R	12800	R	17800	R
2900	S	7900	S	12900	S	17900	S
3000	T	8000	T	13000	T	18000	T
3100	J	8100	U	13100	U	18100	U
3200	V	8200	V	13200	V	18200	V
3300	W	8300	W	13300	W	18300	W
3400	X	8400	X	13400	X	18400	X
3500	Y	8500	Y	13500	Y	18500	Y
3600	Z	8600	Z	13600	Z	18600	Z
3700	[	8700	[	13700	[	18700	[
3800	]	8800	]	13800	]	18800	]
3900	†	8900	†	13900	†	18900	†
4000	(	9000	(	14000	(	19000	(
4100	)	9100	)	14100	)	19100	)
4200	+	9200	+	14200	+	19200	+
4300	=	9300	=	14300	=	19300	=
4400	<	9400	<	14400	<	19400	<
4500	>	9500	>	14500	>	19500	>
4600	\$	9600	\$	14600	\$	19600	\$
4700	!	9700	!	14700	!	19700	!
4800	@	9800	@	14800	@	19800	@
4900	?	9900	?	14900	?	19900	?
5000	%	10000	%	15000	X	20000	X

== INPUT CARD: XOBS=22, YOBS=18, COMMENT='THIS IS AN ALTERNATIVE WAY TO SET OBSERVER POSTION',

USER REQUEST: XOBS = 22
XOBS SET TO 22
USER REQUEST: YOBS = 18
YOBS SET TO 18
USER REQUEST: COMMEN =
THIS IS AN ALTERNATIVE WAY TO SET OBSERVER POSTION

== INPUT CARD: COMMENT='DEMONSTRATE WEIGHTED VIEW OPTIONS', MTITLE='WEIGHTED\$MAP',

USER REQUEST: COMMEN =
DEMONSTRATE WEIGHTED VIEW OPTIONS
USER REQUEST: MTITLE =
WEIGHTED MAP
MAP TITLE IS: WEIGHTED
MAP

== INPUT CARD: AWON, VIEW, MAP, TABLE, AWOFF, COMMENT='DEFINE DISTANCE WEIGHTING FUNCTION',

USER REQUEST: AWON
VISIBILITY ANALYSIS WILL BE WEIGHTED BY THE ASPECT OF EACH CELL RELATIVE TO THE OBSERVER.
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

=====

X ORS	22	
Y ORS	18	
RADIUS	1.500	(MILES)
	2.414	(KILOMETERS)
DELTA X	.20	
DELTA Y	.17	
SCALE	24000.00	
XMIN	1	
XMAX	36	
YMIN	1	
YMAX	52	
ZANGLE	-90.00	
ZBIAS	0	
SECTORS	0	

VISIBILITY WILL BE WEIGHTED BY ASPECT RELATIVE TO THE OBSERVER.

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 184 CELLS (.88 SQUARE MILES,
563.21 ACRES, 1391.71 HECTARES.)

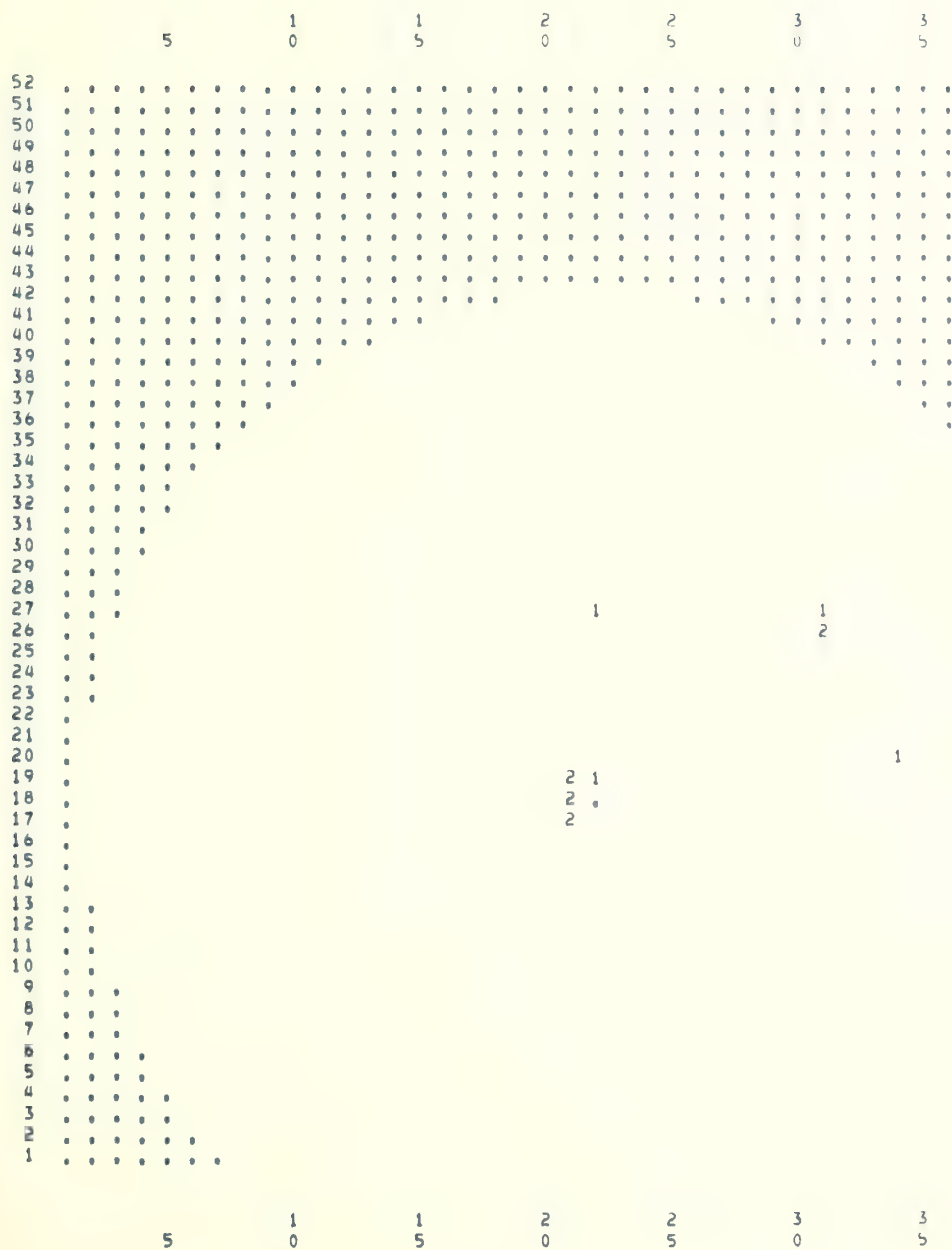
USER REQUEST: MAP

MAP OF TIMES SEEN WEIGHTED BY ASPECT RELATIVE TO THE OBSERVER
FOR 1 OBSERVER(S).

EACH CELL IS GIVEN A SCORE OF 0 TO 10 FOR EACH OBSERVER.
THESE ARE CUMULATED OVER OBSERVER POINTS.
FOR DISPLAY THIS SUM IS DIVIDED BY THE NUMBER OF OBSERVERS
SO THAT THE MAP DISPLAYS A NUMBER FROM 0 TO 10 FOR EACH CELL
WHICH IS AN AVERAGE WEIGHTED VIEW OVER ALL OBSERVERS.

WEI GATED

MAP



USER REQUEST: TABLE

TABLE OF TIMES SEEN WEIGHTED BY ASPECT RELATIVE TO THE OBSERVER
FOR 1 OBSERVER(S).

THE NUMBER ASSOCIATED WITH EACH CELL IS THE SUM OF NUMBERS
BETWEEN 0 AND 10 FOR EACH OBSERVER POINT, WHERE A WEIGHT OF 1,
IS ASSIGNED 10, A WEIGHT OF .5 BECOMES 5, ETC.

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	1836	8.78	5619.83	15886.85
1	21	.10	64.28	158.84
2	6	.03	18.37	45.58
3	5	.02	15.30	37.82
4	1	.00	3.06	7.56
5	1	.00	3.06	7.56
6	1	.00	3.06	7.56
27	1	.00	3.06	7.56

USER REQUEST: AWOFF
WEIGHTING BY ASPECT RELATIVE TO THE OBSERVER IS TURNED OFF.
USER REQUEST: COMMAN =
DEFINE DISTANCE WEIGHTING FUNCTION

== INPUT CARD: NO DWTP, T POINT=(0.5, 1.), TPOINT=(1.0, 0.5), CLEAR, D W ON, VIEW, MAP, TABLE,

USER REQUEST: NODWTP
NO DISTANCE WEIGHT FUNCTION TURNING POINTS. FUNCTION WEIGHT WILL BE 1.0 FOR ALL DISTANCES.

USER REQUEST: TPOINT = (.50, 1.00)
DISTANCE WEIGHT FUNCTION TURNING POINT 1 IS AT DISTANCE = .50 AND HAS A WEIGHT OF 1.00
USER REQUEST: TPOINT = (1.00, .50)
DISTANCE WEIGHT FUNCTION TURNING POINT 2 IS AT DISTANCE = 1.00 AND HAS A WEIGHT OF .50
USER REQUEST: CLEAR

COUNT FIELD CLEARED FOR CELLS IN THE CURRENT SUBRECTANGLE

USER REQUEST: DWON
VISIBILITY ANALYSIS WILL BE WEIGHED BY THE DISTANCE OF EACH CELL FROM THE OBSERVER
ACCORDING TO THE CURRENT DISTANCE WEIGHTING FUNCTION.
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

```
=====
X ORS      22
Y ORS      18
RADIUS      1,500 (MILES)
            2,414 (KILOMETERS)
DELTA X     .20
DELTA Y     .17
SCALE      24000.00
XMIN         1
XMAX         36
YMIN         1
YMAX         52
ZANGLE      -90.00
ZBIAS        0
SECTORS      0
=====
```

VISIBILITY WILL BE WEIGHTED BY DISTANCE FROM THE OBSERVER.

```
-----
DISTANCE    WEIGHT
-----
.50         1.00
1.00        .50
-----
```

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 184 CELLS (.88 SQUARE MILES,
563.21 ACRES, 1391.71 HECTARES.)

USER REQUEST: MAP

WENTEN

APP

	5	1 0	1 5	2 0	2 5	3 0	3 5
52	.	.	.	.	.	.	.
51	.	.	.	.	.	.	.
50	.	.	.	.	.	.	.
49	.	.	.	.	.	.	.
48	.	.	.	.	.	.	.
47	.	.	.	.	.	.	.
46	.	.	.	.	.	.	.
45	.	.	.	.	.	.	.
44	.	.	.	.	.	.	.
43	.	.	.	.	.	.	.
42	.	.	.	.	.	.	.
41	.	.	.	.	.	.	.
40	.	.	.	.	.	.	.
39	.	.	.	.	.	.	.
38	.	.	.	.	.	.	.
37	.	.	.	.	.	.	.
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27	.	.	.	.	.	.	.
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13	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.
3	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.
1	.	.	.	.	.	.	.

== INPUT CARD: CLEAR, COMMENT='NOW BOTH WEIGHTING METHODS', A W ON, VIEW, MAP, A W OFF, D W OFF,

USER REQUEST: CLEAR

COUNT FIELD CLEARED FOR CELLS IN THE CURRENT SUBRECTANGLE

USER REQUEST: COMMENT =
NOW BOTH WEIGHTING METHODS

USER REQUEST: AWON
VISIBILITY ANALYSIS WILL BE WEIGHTED BY THE ASPECT OF EACH CELL RELATIVE TO THE OBSERVER.
USER REQUEST: VIEW

VISIBILITY ANALYSIS WILL BE PERFORMED WITH THE FOLLOWING PARAMETERS:

=====

X OBS	22	
Y OBS	18	
RADIUS	1.500	(MILES)
	2.414	(KILOMETERS)
DELTA X	.20	
DELTA Y	.17	
SCALE	24000.00	
XMIN	1	
XMAX	36	
YMIN	1	
YMAX	52	
ZANGLE	-90.00	
ZBIAS	0	
SECTORS	0	

VISIBILITY WILL BE WEIGHTED BY ASPECT RELATIVE TO THE OBSERVER.

VISIBILITY WILL BE WEIGHTED BY DISTANCE FROM THE OBSERVER.

DISTANCE	WEIGHT
-----	-----
.50	1.00
1.00	.50

ANALYSIS COMPLETE.
THIS OBSERVER CAN SEE 184 CELLS (.88 SQUARE MILES,
563.21 ACRES, 1391.71 HECTARES.)

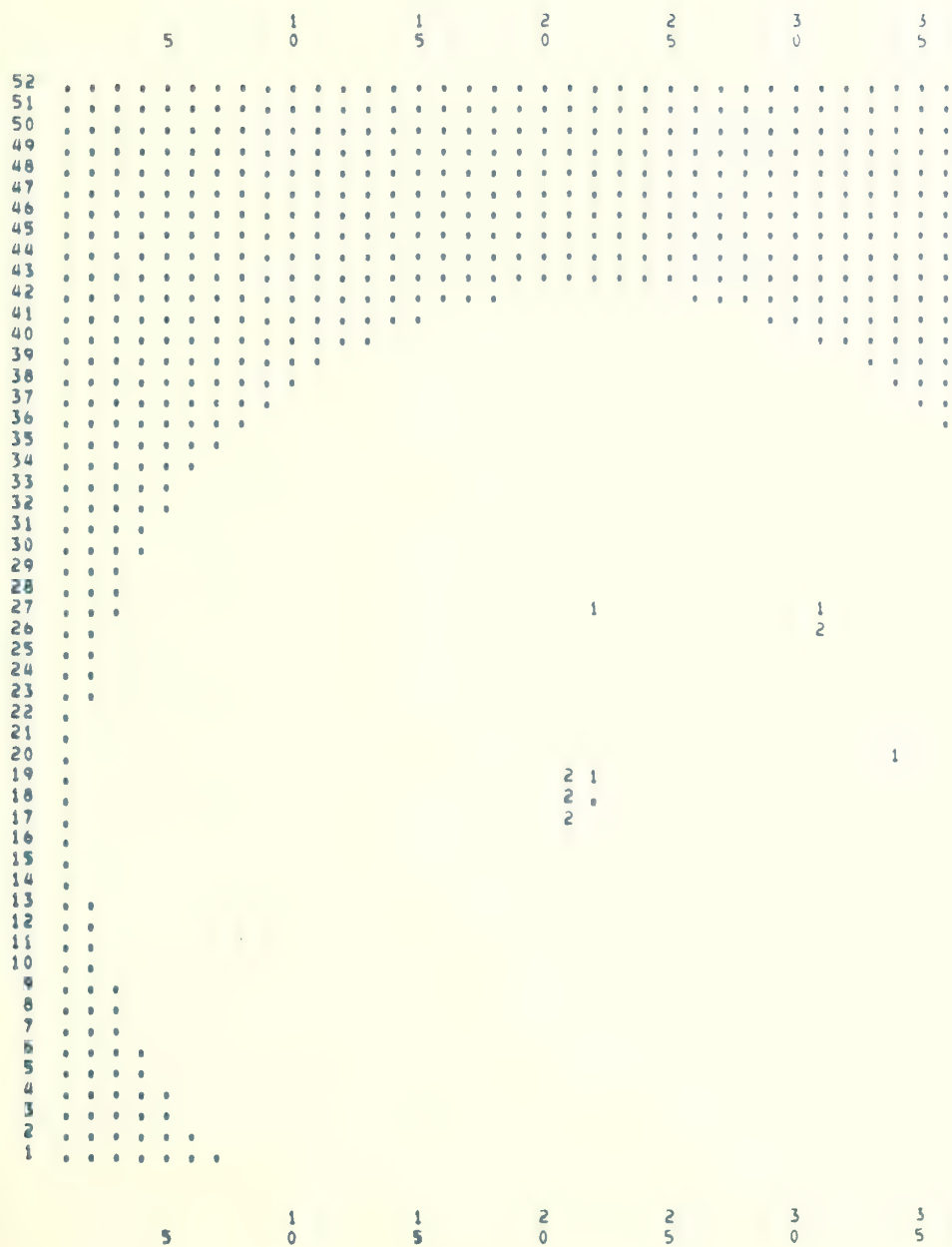
USER REQUEST: MAP

MAP OF TIMES SEEN WIEGHTED BY DISTANCE FROM THE OBSERVER
AND BY ASPECT RELATIVE TO THE OBSERVER FOR 1 OBSERVER(S).

EACH CELL IS GIVEN A SCORE OF 0 TO 10 FOR EACH OBSERVER.
THESE ARE CUMULATED OVER OBSERVER POINTS.
FOR DISPLAY THIS SUM IS DIVIDED BY THE NUMBER OF OBSERVERS
SO THAT THE MAP DISPLAYS A NUMBER FROM 0 TO 10 FOR EACH CELL
WHICH IS AN AVERAGE WEIGHTED VIEW OVER ALL OBSERVERS.

HEIGHTS

MAP



USER REQUEST: AWCFF
 WEIGHTING BY ASPECT RELATIVE TO THE OBSERVER IS TURNED OFF.
 USER REQUEST: DWCFF
 DISTANCE WEIGHTING IS TURNED OFF.

== INPUT CARD: COMMENT='DEFINE SOME SLOPE CLASSES,'

USER REQUEST: COMMEN =
 DEFINE SOME SLOPE CLASSES,

== INPUT CARD: CLASS(1)=(0.,25.), CLASS(2)=(25.,50.),CLASS(3)=(50,1000.), N CLASS=3,

USER REQUEST: CLASS (1) = (.00, 25.00)
 CLASS(1) WILL BE FROM .00 TO 25.00
 USER REQUEST: CLASS (2) = (25.00, 50.00)
 CLASS(2) WILL BE FROM 25.00 TO 50.00
 USER REQUEST: CLASS (3) = (50.00, 1000.00)
 CLASS(3) WILL BE FROM 50.00 TO 1000.00
 USER REQUEST: NCLASS = 3
 NCLASS SET TO 3

== INPUT CARD: COMMENT='FOR SLOPE, CLASSES ARE TAKEN AS SLOPES IN PERCENT',

USER REQUEST: COMMEN =
 FOR SLOPE, CLASSES ARE TAKEN AS SLOPES IN PERCENT

== INPUT CARD: MTITLE='USER SLOPEMAP',

USER REQUEST: MTITLE =
 USER SLOPE MAP
 MAP TITLE IS: USER SLOPE
 MAP

== INPUT CARD: U SLOPE, TABLE, MAP,

USER REQUEST: USLOPE
 SLOPE CALCULATED BY USER-SPECIFIED CLASSES

USER REQUEST: TABLE

TABLE OF SLOPE BY USER-DEFINED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	.00	25.00
2	25.00	50.00
3	50.00	1000.00

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
1	1272	6.08	3893.48	9620.96
2	567	2.71	1735.54	4288.59
3	33	.16	101.01	249.60

USER REQUEST: MAP

MAP OF SLOPE BY USER-SPECIFIED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	.00	25.00
2	25.00	50.00
3	50.00	1000.00

USER

SLIDE

MAP

	5	10	15	20	25	30	35
52	1	1	1	1	1	1	1
51	2	2	1	1	1	1	1
50	1	1	1	1	1	1	1
49	2	2	1	1	1	1	1
48	1	1	1	1	1	1	1
47	1	1	1	1	1	1	1
46	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1
44	1	1	1	1	1	1	1
43	1	2	2	1	1	1	1
42	1	1	2	2	1	1	1
41	1	1	1	2	1	2	2
40	1	1	1	1	2	2	2
39	1	1	1	1	1	1	1
38	1	1	1	1	1	2	2
37	1	1	1	1	1	2	2
36	1	1	2	1	2	1	1
35	1	1	2	1	1	1	1
34	2	1	2	1	1	1	1
33	1	2	2	1	1	1	1
32	1	2	2	1	1	1	1
31	1	2	2	1	1	1	1
30	1	2	2	1	1	1	1
29	1	2	2	1	1	1	1
28	1	2	1	1	1	1	1
27	1	2	1	1	1	1	1
26	1	2	1	1	1	1	1
25	2	2	1	1	1	1	1
24	1	1	1	1	1	1	1
23	1	2	1	1	1	1	1
22	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1
20	1	2	1	1	1	1	1
19	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1
17	1	2	1	1	1	1	1
16	2	2	2	2	1	1	1
15	2	2	2	2	1	1	1
14	2	2	2	1	1	1	1
13	2	2	1	1	1	1	1
12	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1
10	2	1	1	1	1	1	1
9	2	2	2	2	2	2	2
8	1	2	1	1	1	1	1
7	1	2	2	3	3	2	2
6	2	2	2	2	2	1	1
5	1	2	2	2	2	1	1
4	2	2	2	2	2	1	1
3	1	2	2	2	2	1	1
2	2	2	2	2	1	1	1
1	1	2	2	1	1	1	1

== INPUT CARD: COMMENT='NOW CALCULATE SLOPE BY THE MAXIMUM SLOPE METHOD', U X SLOPE,

USER REQUEST: COMMEN =
NOW CALCULATE SLOPE BY THE MAXIMUM SLOPE METHOD
USER REQUEST: UXSLOP

MAXIMUM SLOPE CALCULATED BY USER-SPECIFIED CLASSES.

== INPUT CARD: TABLE, MAP,

USER REQUEST: TABLE

TABLE OF MAXIMUM SLOPE BY USER-DEFINED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
-----	-----	-----
1	.00	25.00
2	25.00	50.00
3	50.00	1000.00

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
=====	=====	=====	=====	=====
0	4	.02	12.24	30.25
1	512	2.45	1567.19	3872.59
2	1084	5.18	3318.03	8198.99
3	272	1.30	832.57	2057.31
=====	=====	=====	=====	=====

USER REQUEST: MAP

MAP OF MAXIMUM SLOPE BY USER-SPECIFIED CLASSES

CLASS	LOWER LIMIT	UPPER LIMIT
-----	-----	-----
1	.00	25.00
2	25.00	50.00
3	50.00	1000.00

USER

SELOPE

MAP

	5	10	15	20	25	30	35
52	2	2	2	2	1	1	1
51	2	2	2	2	2	1	1
50	2	2	2	2	2	1	1
49	2	2	2	2	1	1	1
48	2	2	2	2	2	1	1
47	1	1	1	1	1	1	1
46	1	1	1	1	1	1	1
45	1	2	1	1	1	1	1
44	2	2	2	1	1	1	1
43	2	2	3	3	2	1	1
42	1	2	3	3	2	1	1
41	1	1	1	2	2	3	2
40	1	1	2	2	3	2	3
39	2	2	2	2	2	2	2
38	2	2	1	2	3	3	3
37	2	1	2	2	3	3	2
36	2	2	2	2	2	2	2
35	2	2	2	2	1	2	2
34	2	3	2	2	1	2	1
33	2	3	2	2	1	1	1
32	2	3	2	2	1	1	1
31	2	2	2	2	1	2	2
30	2	2	2	2	3	2	2
29	2	2	3	2	3	2	2
28	2	2	3	2	2	2	2
27	2	2	3	2	2	2	2
26	2	2	2	1	1	2	2
25	2	2	2	1	2	2	2
24	2	2	2	1	2	2	1
23	2	2	2	1	2	2	1
22	1	2	2	1	2	2	1
21	1	2	2	2	2	2	2
20	2	2	2	1	2	2	2
19	2	1	2	1	3	2	2
18	1	1	2	1	3	2	2
17	2	2	2	2	3	2	2
16	3	2	2	2	2	1	2
15	3	3	2	2	2	2	2
14	3	2	2	2	2	2	2
13	3	2	2	2	1	2	2
12	2	2	2	2	2	2	2
11	2	2	2	2	2	2	2
10	2	2	2	2	2	2	2
9	2	2	3	3	3	2	2
8	2	2	3	3	3	3	2
7	2	2	3	3	3	3	2
6	2	3	2	2	3	1	2
5	3	2	2	2	2	2	2
4	3	2	2	2	2	2	2
3	2	2	2	2	2	2	2
2	2	3	2	2	2	2	2
1	2	2	3	2	2	1	2

== INPUT CARD; M TITLE='ELEVATION\$CLASS MAP',

USER REQUEST: M TITLE =
ELEVATION CLASS MAP
MAP TITLE IS: ELEVATION
CLASS MAP

== INPUT CARD; COMMENT='DEFINE SOME ELEVATION CLASSES', CLASS(1)=(0,4000), CLASS(2)=(4000,5000)

USER REQUEST: COMMENT =
DEFINE SOME ELEVATION CLASSES

USER REQUEST: CLASS (1) = (,00, 4000,00)
CLASS(1) WILL BE FROM ,00 TO 4000,00

== INPUT CARD; , CLASS(3)=(5000,6000), CLASS(4)=(6000,7000), CLASS(5)=(7000, 10000), NCLASS=

USER REQUEST: CLASS (2) = (4000,00, 5000,00)
CLASS(2) WILL BE FROM 4000,00 TO 5000,00
USER REQUEST: CLASS (3) = (5000,00, 6000,00)
CLASS(3) WILL BE FROM 5000,00 TO 6000,00
USER REQUEST: CLASS (4) = (6000,00, 7000,00)
CLASS(4) WILL BE FROM 6000,00 TO 7000,00
USER REQUEST: CLASS (5) = (7000,00, 10000,00)
CLASS(5) WILL BE FROM 7000,00 TO 10000,00

== INPUT CARD; S, U ELEV, TABLE, MAP,

USER REQUEST: NCLASS = 5
NCLASS SET TO 5
USER REQUEST: U ELEV

ELEVATIONS GROUPED BY USER-SPECIFIED CLASSES

USER REQUEST: TABLE

TABLE OF ELEVATIONS BY USER-DEFINED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	,00	4000,00
2	4000,00	5000,00
3	5000,00	6000,00
4	6000,00	7000,00
5	7000,00	10000,00

CLASS	CELLS	AREA, SQUARE MILES	ACRES	HECTARES
1	1	,00	3,06	7,56
2	737	3,52	2255,89	5574,41
3	1131	5,41	3461,89	8554,48
4	3	,01	9,18	22,69

USER REQUEST: MAP

MAP OF ELEVATIONS BY USER-SPECIFIED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	,00	4000,00
2	4000,00	5000,00
3	5000,00	6000,00
4	6000,00	7000,00
5	7000,00	10000,00

ELFVATTON

CLASS MAP

	5	10	15	20	25	30	35
52	2	2	2	2	2	2	3
51	2	2	2	2	2	2	3
50	2	2	2	2	2	2	3
49	2	2	2	2	2	2	3
48	2	2	2	2	2	2	3
47	2	2	2	2	2	2	3
46	2	2	2	2	2	2	3
45	2	2	2	2	2	2	3
44	2	2	2	2	2	2	3
43	2	2	2	2	2	2	3
42	2	2	2	2	2	2	3
41	2	2	2	2	2	2	3
40	2	2	2	2	2	2	3
39	2	2	2	2	2	2	3
38	2	2	2	2	2	2	3
37	2	2	2	2	2	2	3
36	2	2	2	2	2	2	3
35	2	2	2	2	2	2	3
34	2	2	2	2	2	2	3
33	2	2	2	2	2	2	3
32	2	2	2	2	2	2	3
31	2	2	2	2	2	2	3
30	2	2	2	2	2	2	3
29	2	2	2	2	2	2	3
28	2	2	2	2	2	2	3
27	2	2	2	2	2	2	3
26	2	2	2	2	2	2	3
25	2	2	2	2	2	2	3
24	2	2	2	2	2	2	3
23	2	2	2	2	2	2	3
22	2	2	2	2	2	2	3
21	2	2	2	2	2	2	3
20	2	2	2	2	2	2	3
19	2	2	2	2	2	2	3
18	2	2	2	2	2	2	3
17	2	2	2	2	2	2	3
16	2	2	2	2	2	2	3
15	2	2	2	2	2	2	3
14	2	2	2	2	2	2	3
13	3	3	3	3	3	3	3
12	3	3	3	3	3	3	3
11	3	3	3	3	3	3	3
10	3	3	3	3	3	3	3
9	3	3	3	3	3	3	3
8	3	3	3	3	3	3	3
7	3	3	3	3	3	3	3
6	3	3	3	3	3	3	3
5	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3
1	3	3	3	3	3	3	3
	5	10	15	20	25	30	35

== INPUT CARD: COMMENT='DEFINE ASPECT SECTORS AND ANALYZE ASPECT BY THEM',

USER REQUEST: COMMEN =
 DEFINE ASPECT SECTORS AND ANALYZE ASPECT BY THEM

== INPUT CARD: CLASS(1)=(350., 360.), CLASS(2)=(0, 10), NCLASS=2,

USER REQUEST: CLASS (1) = (350.00, 360.00)
 CLASS(1) WILL BE FROM 350.00 TO 360.00
 USER REQUEST: CLASS (2) = (.00, 10.00)
 CLASS(2) WILL BE FROM .00 TO 10.00
 USER REQUEST: NCLASS = 2
 NCLASS SET TO 2

== INPUT CARD: COMMENT='ASPECTS OUTSIDE THE DEFINED CLASSES WILL BE PUT IN CLASS ZERO',

USER REQUEST: COMMEN =
 ASPECTS OUTSIDE THE DEFINED CLASSES WILL BE PUT IN CLASS ZERO

== INPUT CARD: MTITLE='USERSASPECTS',

USER REQUEST: MTITLE =
 USER ASPECTS
 MAP TITLE IS: USER
 ASPECTS

== INPUT CARD: U ASPECT, TABLE, MAP,

USER REQUEST: UASPEC

ASPECT CALCULATED BY USER-SPECIFIED CLASSES

USER REQUEST: TABLE

TABLE OF ASPECT BY USER-DEFINED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	350.00	360.00
2	.00	10.00

CLASS	CELLS	AREA: SQUARE MILES	ACRES	HECTARES
0	1742	8.33	5332.11	13175.87
1	23	.11	70.40	173.96
2	107	.51	327.52	809.31

USER REQUEST: MAP

MAP OF ASPECT BY USER-SPECIFIED CLASSES.

CLASS	LOWER LIMIT	UPPER LIMIT
1	350.00	360.00
2	.00	10.00

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REPORTS

	5	1 0	1 5	2 0	2 5	3 0	3 5
52	2 2 2						
51	2 2	2		2 2			
50				2			
49							
48							
47				2 2			
46				2 2			
45	2						
44	2						
43							
42	2	2 2					
41		1 2					
40			2				
39	2			2 2	1 2 1 1 2 2		
38		2	2 2	2	1 2 1	1 2 1 1	
37		2	2 2	2	1	2 2 1 2	
36		2	2	2		2 2	
35			2 2	2			
34			2 2	2 2			
33		2	2	1			
32				2			
31			2	2 2 2			2
30			2	2			
29			2				
28				2			
27							
26							
25							
24					2 2		
23							
22							
21					2 2	2 2	2
20					2	1 2 2 2	2 2
19					2	2 2	
18					2		
17		2					
16		2					
15			1				
14			2 2				2
13	2 1	2	2 2				2
12	2		2				
11			1				
10		2 2		1			
9		2		2			
8		1		1			
7		2 1					
6					2		
5							2
4							
3							
2							2
1							
	5	1 0	1 5	2 0	2 5	3 0	3 5

APPENDIX II

This appendix is intended to illustrate the use of a preprocessor program with data that is in a form that cannot be read directly by VIEWIT. The preprocessor is a simple program that, in this case, reads the data from cards and places it in a temporary file in a binary format. This file could be cataloged so it would remain in existence from one run to another; if this is done, the preprocessing will need to be done only once rather than every time an analysis with VIEWIT is needed.

Following the preprocessor, VIEWIT is called into execution and directed to read the data as prepared by the preprocessor program, and then to perform a few analyses.

If the data matrix is larger than the computer memory available to the user, then the preprocessor should handle the data a row (or a column) at a time and be dimensional for only one row (or one column).

```

@MDG    APPENDIX 2 - PREPROCESSING OF DATA
@FOR,IS PREPRG
C THIS PROGRAM READS IN A SET OF DATA WHICH WAS DIGITIZED
C MANUALLY IN THREE VERTICAL STRIPS. EACH STRIP WAS PUNCHED ONTO A SET OF
C 136 CARDS. THE DATA DECK CONTAINS THE CARDS FOR THE LEFTMOST STRIP,
C THEN THE NEXT, THEN THE FINAL STRIP. THE DATA ARRAY IS 82 BY 136.
C THE FIRST TWO STRIPS ARE 37 COLUMNS WIDE, AND THE FINAL STRIP IS 8
C COLUMNS WIDE. ELEVATIONS ARE DIGITIZED TO THE NEAREST HUNDRED FEET,
C SO THAT THE CARDS CONTAIN ONLY 2 DIGITS (THOUSANDS AND HUNDREDS)
C FOR EACH CELL.
C
C THIS PROGRAM READS IN THIS DATA AND CONVERTS IT TO BINARY ROWS WHICH
C CAN BE READ IN BY VIEWIT.
C
    DIMENSION AREA(82,136)
    DIMENSION ISTART(3),ISTOP(3)
    DATA ISTART/1,38,75/
    DATA ISTOP/37,74,82/
C
C READ THE THREE STRIPS
    DO 100 ISTRIP=1,3
C FIND START AND END INDEX FOR THIS STRIP
    K1=ISTART(ISTRIP)
    K2=ISTOP(ISTRIP)
C READ THE ROWS FOR THIS STRIP
    DO 200 J=1,136
200 READ 10,(AREA(K,J),K=K1,K2)
    10 FORMAT(3F2,0)
    100 CONTINUE
C
C WRITE OUT THE DATA BY ROWS
    DO 300 J=1,136
300 WRITE(2)(AREA(K,J),K=1,82)
C
    STOP
    END
@XQT
*****
* DATA CARDS GO HERE *
*****
@XQT PSW=VIEWIT.
TITLE='PREPROCESSOR DEMONSTRATION ON MOUNT RUSHMORE DATA',
NROWS=136,NCOLS=82,BINARY,FILE='2.',COMMENT='THIS IS WHERE THE PREPROCESSOR WROTE
THE DATA', BINARY, Z SCALE = 100, COMMENT='ZSCALE CORRECTS FOR THE FACT THAT
ONLY THE FIRST TWO DIGITS APPEARED ON THE DATA CARDS',READ,
M TITLE='SLOPE MAP', SLOPE, TABLE, GMAP,
STOP,
@ FIN
**

```


PACIFIC
SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

USDA FOREST SERVICE
GENERAL TECHNICAL
REPORT PSW-12 /1975

RAMP:
a computer system for
mapping regional areas

Bradley B. Nickey

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1975. **RAMP: a computer system for mapping regional areas.** USDA Forest Serv. Gen. Tech. Rep. PSW-12, 9 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Until 1972, the U.S. Forest Service's Individual Fire Reports recorded locations by the section-township-range system. These earlier fire reports, therefore, lacked congruent locations. RAMP (Regional Area Mapping Procedure) was designed to make the reports more useful for quantitative analysis. This computer-based technique converts locations expressed in section-township-range notations into latitude-longitude coordinates. Two subsystems make up RAMP. The technique can be applied to other types of land-management problems.

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Retrieval Terms: fire case histories; burn pattern; mapping systems; coordinates; locations; computer programs; RAMP; Regional Area Mapping Procedure.

The Author

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Much information useful for land-use planning remains untapped by computerized retrieval systems because of the cost of correcting inadequate land locators. A typical example of this problem is found in the U. S. Forest Service's Individual Fire Report (Form 5100-29). In 1972, the form was revised to record fire locations in degrees and minutes of latitude and longitude. But until then, the section, township, and range in which the fire started were recorded. This location is appropriate for statistical tabulations, but is not suitable for quantitative analysis. Therefore, much of the information in these earlier reports is not available to the fire manager and planner.

To tap this reservoir of historical information, a computer-based technique called the Regional Area Mapping Procedure (RAMP) was developed. RAMP is designed to provide longitude and latitude values of section corners and midpoints from digitized map locations of townships.

This report describes RAMP, its characteristics, digitization requirements, and computer software, and suggests how the system could be used in solving other types of land management problems.

Instructions on how to prepare input for the computer system are found in the *Procedural Guide for the RAMP Quantization and Coding Process*. The Guide is available upon request to: Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

INDIVIDUAL FIRE REPORTS

The individual Fire Reports are a primary source of wildfire information used in fire prevention, fuel treatment, and fire planning. Generally, the planning techniques currently used require manual processing of this information. But computer-produced tabulations and summary reports are available by using keypunched copies of the form.

Analyzing the spatial information in the Individual Fire Reports by advanced quantitative techniques would require a computer. However, such work has been hampered by the format of the report—particularly its location of the fire by the use of the section-township-range system. The township and section pattern of the Deschutes National Forest, in

Oregon, illustrates the complexity of the problem (fig. 1).

Sections are nominally 1 mile square; townships are 6 miles by 6 miles and contain 36 sections. The half townships (T.25 1/2 S.), however, contain six sections, and one of them is much smaller than the others (see section 31, fig. 1). Irregularities such as these preclude the use of the existing locator for computer analysis.

Spatial analysis of the Individual Fire Reports archives requires a change to a congruent locator, such as degrees latitude and longitude. Highly accurate computer-based mapping systems that use legal land descriptors, least-square error techniques, and other sophisticated methods are available, but are costly (Swann and others 1970). For many jobs a high degree of locator accuracy is not critical.

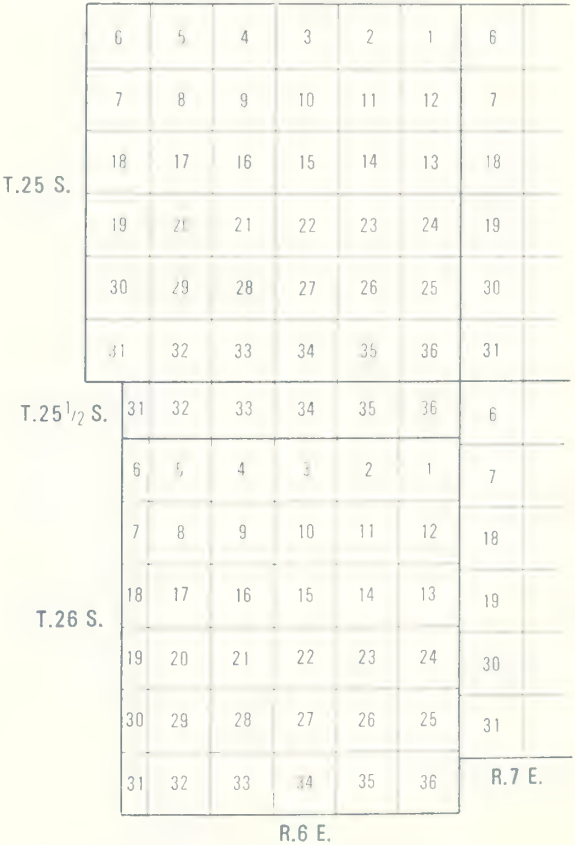


Figure 1—The township configuration found on the Deschutes National Forest, Oregon, includes half townships (6 sections) as well as full ones (36 sections). Some of the sections may be much smaller than others.

RAMP

RAMP (Regional Area Mapping Procedure) accepts the errors inherent in a map, and converts the section-corner projections into degrees latitude and longitude. Briefly, the system involves digitizing the locations of the corners of a few sections in each township. Variations from nominal size are identified and distributed among the sections, by procedures similar to the General Land Office survey rules for handling errors. Finally, the locations of all remaining sections and the centroid of each section are computed. With this system, digitizing one township can result in as many as 35 section locations being calculated automatically by the computer. Locations by latitude/longitude and section/range/township are then cross-referenced.

RAMP consists of two interrelated subsystems: one converts section corner locations on a map to a digital recording of an x-y coordinate in a form compatible for computer processing; the other provides instructions that take advantage of township surveying principles and section numbering configurations to minimize the amount of digitizing.

DIGITIZATION REQUIREMENTS

Many different characteristics exist on commercially available digitizers. Some of the more critical differences are (a) fixed versus variable length digital records—a record is the unit of data to be transmitted to the computer, (b) number of x-y coordinate points that can be entered on a record, (c) availability or limitations or both on keying information into a record, and (d) coordinate alignment procedures. Each difference affects the digitizing and coding procedures. In turn, each procedure influences the computer program used to process the digitized information.

In RAMP, nine different digitized records are used. They provide the essential information for (a) development of scale coefficients for conversion of x-y corner locations to degrees latitude and longitude, (b) alignment of the x axis of the digitizer coordinate system with the longitude axis of the map, (c) identification of the latitude and longitude at the origin of the digitizer coordinate system, (d) determination of the latitude and longitude of the corner points and centroid of a section(s), and (e) comparison of known map coordinate locations with calculated values. An 80-column punchcard, limited to three sets of digitized x-y coordinate points and 41 columns of keyed information, provides the means for linking these records to the computer subsystem.

The time required for digitizing is a function of the number of townships within a forest, the amount of key information required, and the number of non-rectangular sections it contains. For example, on the Clearwater National Forest, in Idaho, it was necessary to digitize 463 records to cover 3646 sections. Many of these records were required to process an extraordinarily large number of nonrectangular sections. This work took about 3-1/2 hours. On the other hand, only 116 records were needed to cover 5411 sections in the Tonto National Forest in Arizona. In this case, about 2 hours were needed to digitize the maps.

The average number of sections calculated for each digitized record for seven forests is 15.4 (*table 1*). However, considerable differences from the average existed for different forests.

ACCURACY

Analysis of the magnitude and direction of calculated locations for 53 points, taken from nine different forest maps, showed no systematic errors over the range of latitude and longitude examined. The computed standard error for latitude was 252 feet and 437 feet for longitude (*table 2*).

The scale of all of the maps digitized was 1/2 inch to 1 mile. The smallest line digitized on these maps was clearly legible at a viewing distance of 5 feet. This would indicate that the lines were at least 0.03 inch wide (Robinson and Sale 1969). A line of this width is equivalent to a distance of 316 feet on the maps analyzed. One of the more accurate computer-based systems accepts calculated points which have an error of less than 200 feet at the latitude/longitude intersections (Swann and others 1970). It would appear from this comparison that the errors associated with RAMP are reasonable—especially for maps of the scale used in the study.

COMPUTER SOFTWARE

Many commercially available digitizers have built-in functions to insure the alignment of the coordinate system with a map system that covers a small geographic area. When this capability is not available, as in RAMP, the computer software must perform these functions. A closely related item is the ability to interrupt a digitized session, remove the map from the digitizer, and then later restart the process so that all new records are adjusted to the original initial origin.

Somewhat less common is a built-in function for the conversion of x-y coordinates developed by digitizing map points to coordinates of latitude and longitude.

Table 1—Efficiency of RAMP, as measured by the average number of sections processed by one digitized record

Forest Unit	Digitized records	Sections processed	Efficiency (sections/record)
Deschutes N.F.	116	4044	34.9
Tonto N. F.	214	5411	25.3
Pike N. F.	123	2765	22.5
Sequoia N. F.	131	2005	22.2
Mendocino C.D.F.R.U.	266	3689	13.9
Sierra N. F.	242	2415	10.0
Clearwater N. F.	463	3646	7.9
Total	1555	23915	
Average	222.1	3416.4	15.4

tude. Within RAMP, conversion to latitude is achieved by using a constant scale factor for each map. However, this factor may change between maps. Because the distance between two latitude lines decreases rapidly as they approach the earth's poles, the conversion to longitude is a variable scale factor depending upon the latitude of the point.

To relate congruent location dimension to a section-township-range locator, three different sets of computer instructions are used in RAMP: (a) one determines the latitude and longitude of the four corners and the midpoint of a single rectangular shaped section; (b) another performs similar calculations for triangular or quadrilateral sections; and (c) the third provides latitude and longitude locations for each section within a township. Both of the first two techniques have an efficiency of 1; that is, for each digitized record, one section is provided with latitude and longitude locations. The third technique can result in an efficiency of up to 36. Lower efficiencies than this are due to the existence of irregular townships.

A full township consists of 36 sections (*fig. 1*). Less than full townships may occur (T.25 1/2S., R.6E., for example). In those instances, generally one or more of the northern rows or western columns of the township or both are absent. Each digitized record must contain three digitized points—coded information containing the unique township and range address—and the number of the section which serves as the intersection of the most western column and the most northern row of the township.

To illustrate, a record for T.25S., R.6E. (*fig. 1*) would contain the digitized northwest and southeast corner points of section 6 and the southeast corner point of section 36. It would also contain the codes T.25S., R.6E., and 6. This information would result in the development of latitude and longitude for each corner and midpoint for all 36 sections. If the record contained an 8 instead of the section number 6, 25 sections would be processed. The section numbers eliminated would be 1-7, 18, 19, 30, and 31. In addition, any oversized or fractional section dimensions in the northern row or western column of the township

Table 2—Known and calculated coordinates of latitude and longitude for 53 points from nine forest maps (scale: 1/2 inch = 1 mile)

Coordinates	Latitude		Longitude	
	Mean	Standard deviation	Mean	Standard deviation
	Degrees			
Known	40.2271	4.6116	111.0928	11.6320
Calculated	40.2272	4.6103	111.0929	11.6311
Error	0.0001	-0.0013	0.0001	-0.0009

or both would be noted by the computer, and appropriate adjustments made in all other sections within the same row or column or both.

The RAMP computer program consists of about 1300 statement lines, written in FORTRAN IV language for an IBM 360/50 Operating System¹, and requires approximately 130K of core to execute. Direct transfer of this program to other systems is limited because of design effects resulting from the interface with the RSS-400 Graphic Quantitizer.

COMPUTER OPERATIONS

Three major categories of calculations are required by RAMP. It provides algorithms to (a) determine and correct for the nonalignment that may exist between the X axis of the digitizer coordinate system and the longitude axis of the map; (b) develop scaling coefficients for converting digitizer coordinates to spherical coordinates of longitude and latitude; and (c) calculate the latitude and longitude of the corners and the midpoints of sections.

Converting Coordinates

Two scaling operations are used by RAMP. Adequate precision is achieved by treating the conversion of Y digitized units to latitude values as a constant within a given National Forest, but it may change in value for a different forest. Two widely separate but known latitude points, selected from one of the two latitude scales on either side of a map, are digitized. The basic FORTRAN equation used to develop the Y conversion coefficient is

$$\text{SCALE}(3) = \text{FLOAT}(\text{IRANGE}) / (60 * \text{YDELTA}) \quad (1)$$

in which:

- SCALE(3) = Y conversion coefficient
- YDELTA = Difference between the two Y coordinates, resulting from the digitization of known latitude values.
- IRANGE = Difference between the two known latitude coordinates digitized for YDELTA.

Because latitudes converge quickly at the earth's poles, the conversion of X digitized units to longitude values is treated as a variable, depending upon the latitude of the point being transformed. Two widely separate but known longitude points are digitized

from the longitude scale on the top of the map. The same operation is repeated on the bottom longitude scale of the map. The X conversion coefficient, being a variable value, is calculated for every point being transformed by incorporating Equation 1 into a conversion coefficient function. The number of X digitization units within a degree of longitude at the top of a map will be less than the equivalent degree measured at the bottom of the map. RAMP uses linear interpolation to approximate this change in dimensions within a National Forest.

The X conversion coefficient function is

$$\text{SCALE}(J) = \text{SCALEX}(1) - \text{SCALEX}(2) \quad (2) \\ * (\text{LATTOP} - \text{SCALE}(3) * \text{LAT}(J)) \\ / (\text{LATTOP} - \text{LATBOT})$$

and

$$\text{SCALE}(I) = \text{FLOAT}(\text{J RANGE}(I)) \quad (3) \\ / (60 * \text{XDELTA}(I))$$

in which

- SCALE(J) = X conversion coefficient at Latitude J.
- SCALEX(I) = X conversion coefficient at the top (I=1) and at the bottom (I=2) longitude scales of the maps.
- LATTOP = Approximate latitude of the top longitude scale, expressed in decimal degrees of latitude.
- LATBOT = Approximate latitude of the bottom longitude scale, expressed in decimal degrees of latitude.
- LAT(J) = Y Coordinate of the point (J) being converted to spherical coordinates. This variable should be expressed in units measured by the digitizer.
- XDELTA(I) = Difference between the two X coordinates, resulting from the digitization of known latitude values at I.
- JRANGE(I) = Difference between the two known longitude coordinates digitized at I.

Aligning Coordinates

If the digitizer coordinate system originated exactly at the center of a 36-inch wide map (scale: ½ inch = 1 mile), an alignment error of 15 minutes between the two coordinate systems would result in a conversion error of about 828 feet for locations near

¹Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

the map edge. And if maps are larger than 36 inches, they would be subjected to even greater errors. In addition, a digitizer operator would be hard pressed to keep alignment errors close to 15 minutes. Many digitizers allow the operator to establish the origin of its coordinate system at any convenient map point. A seldom used but more universal requirement is the ability to perform rectangular coordinate axis translation or rotations, or both. This procedure would allow the interruption of a digitization process, removal of the map from the equipment, and continuation of the digitization with all measures transformed to the initial coordinate system. The RAMP computer program provides for all of these procedures.

The most simple alignment correction problem exists when the longitude and latitude at the origin of the rectangular coordinate system is known. The angle of rotation between the X axis and the longitude axis is found by

$$\text{THETA} = \text{ARSIN}(D/(\text{SCALE}(1)*\text{SCALE}(2) * (YY1*XX2 - YY2*XX1))) \quad (4)$$

and

$$D = XX2*\text{SCALE}(2)*(LZERO - LONE) + XX1*\text{SCALE}(1)*(LTWO - LZERO) \quad (5)$$

in which

- THETA = Angle separating the X axis of the digitizer with a longitude line on the map.
- LZERO = Longitude at the origin of the rectangular coordinate system, expressed in decimal degrees of longitude.
- LONE = Longitude at a known point on the map. This point should be located to the right of LZERO and have a known value less than LZERO, and be expressed in decimal degrees of longitude.
- LTWO = Longitude at a known point on the map which has a value greater than LZERO, expressed in decimal degrees of longitude.
- XX1,YY1 = X and Y digitization value of LONE, expressed in rectangular coordinate units.
- XX2,YY2 = X and Y digitization value of LTWO, expressed in rectangular coordinate units.
- SCALE(K) = Equation 2 solved for point YY1 (K=1) and YY2 (K=2), respectively.

When the map coordinates at the origin of the digitizer are unknown, a much more complex problem exists. Finding the angle of rotation and the longitude and latitude at the origin requires the solution of two transcendental equations containing three unknowns. Since the number of unknowns exceeds the number of available expressions, an iterative process for finding the solution is required. Fortunately, the range over which the iteration must be performed is small. Most "unassisted" digitizer operators can align the two coordinate systems within a range of several degrees. The two equations that need to be solved are

$$\begin{aligned} \text{XFUN} = & \text{ABS}(\text{LONE} - \text{LTWO}) \\ & - \text{ABS}((\text{SCALE}(2)*XX2 \\ & - \text{SCALE}(1)*XX1)*\text{COS}(\text{ARG}) \\ & - (\text{SCALE}(1)*YY1 \\ & - \text{SCALE}(2)*YY2)*\text{SIN}(\text{ARG}) \end{aligned} \quad (6)$$

and

$$\begin{aligned} \text{YFUN} = & \text{ABS}(\text{LATONE} - \text{LATWO}) - \text{ABS} \\ & (((YY2 - YY1)*\text{COS}(\text{ARG}) \\ & - (XX2 - XX1)*\text{SIN}(\text{ARG})*\text{SCALE}(3))) \end{aligned} \quad (7)$$

in which

- XFUN, YFUN = Conditional transcendental equations containing the unknown angle of rotation.
- ARG = An assumed angle of rotation between the X axis of the digitizer coordinate system and a longitude line on the map.
- LATONE, LATWO = Known latitudes at LONE and LTWO respectively, expressed in decimal degrees of latitude.

If the two coordinate axes have been closely aligned before digitizations, only one angle of rotation will exist between ± 10 degrees that will yield equivalent solutions for Equations 6 and 7. If both equations are equal, ARG is nearly equal to THETA. The map coordinates at the origin of the rectangular coordinate system are now found by:

$$\text{LZERO} = \text{LONE} + \text{XX1}*\text{SCALE}(1) \quad (8)$$

and

$$\text{LATO} = \text{LATONE} - \text{YY1}*\text{SCALE}(3) \quad (9)$$

in which

LATO = Latitude at the origin of the rectangular coordinate system, expressed in decimal degrees of longitude.

An interrupted digitization effort—one that requires establishment of a new origin—will normally require both a translation and rotation transformation to align the new origin with the initial origin. This allows all the digitized records of a map to be processed during a single computer run. Two flagged points digitized during the initial effort are redigitized. The angle of rotation between the old and the new is found by

$$\text{THETAN} = \text{ARCOS}((C*C - A*A - B*B) / (-2.*A*B)) \quad (10)$$

in which

$$A = (X2OLD - X1OLD)**2 + (Y2OLD - Y1OLD)**2 \quad (11)$$

$$B = (X2NEW**2 + Y2NEW**2) \quad (12)$$

and

$$C = (X2NEW + X1OLD - X2OLD)**2 + (Y2NEW + Y1OLD - Y2OLD)**2 \quad (13)$$

in which

THETAN	= Rotation angle required to align the current rectangular coordinate system of the digitizer to the original rectangular coordinate system.
$\begin{Bmatrix} X1OLD, Y1OLD \\ X2OLD, Y2OLD \end{Bmatrix}$	= Rectangular coordinates from the initial digitization effort. Each point was previously marked as a potential future reference location.
$\begin{Bmatrix} X1NEW, Y1NEW \\ X2NEW, Y2NEW \end{Bmatrix}$	= Rectangular coordinates from the new digitization effort of the above flagged locations.

The translation constants for X and Y axes are, respectively

$$XADJ = X1OLD \text{ and } YADJ = Y1OLD \quad (14),(15)$$

Methods to perform the actual translation or rotation, or both, utilizing the results from Equations 4 to 15 are available in most mathematical handbooks (Selby and others 1965).

Mapping Sections

A section is considered mapped when all corners of the boundary and the centroid of the area within the boundary are described by longitude and latitude coordinates. Attachment of the section-township-range label to the coordinates creates a suitable cross-reference index record for the individual Fire Reports.

Three methods exist within RAMP for mapping sections: (a) one provides latitude and longitude locations of the four corners and midpoint of each section within a township; (b) another performs similar calculations for a triangular or quadrilateral section; and (c) the last procedure determines the latitude and longitude for a single rectangular section.

The first method reduces the number of digitized points required to process a township by taking advantage of the surveying and identity coding standards of sections within a township.

Three sets of digitized points, the township and range codes, and at least one but not more than two section numbers are needed to process a township. The northwest corner of the section that serves as the intersection of the top row and leftmost column of the township is digitized and referred to as X1 and Y1. The southeast corner of this same section is digitized and referred to as X2 and Y2. The number of this section, (ISECT) is also recorded. The last point digitized—X3, Y3—is the southeast corner of the section that occupies the intersection of the rightmost column and bottom row of the township. If any righthand columns or southern rows of the township are missing, the section number (JSECT) is also recorded.

In RAMP, all townships are initially assumed to be made up of 36 sections. Each row and column in a full township also has a reference number associated with it. For example, section number 6 is defined as a member of column 1, row 1. Section number 5 is a member of column 2, row 1. The intersection of column 1, row 2 would then be occupied by section number 7. Thus, the origin of the reference system is considered to be section number 6. Columns moving to the east increase in number as they move away from the origin. Rows increase as they move south from the origin. With this reference system, the actual number of sections and their configuration in the township can be determined from values of ISECT and JSECT.

The reference number of the most northern row of the township can be found by

$$LY = (\text{ISECT} - 1) / 6 + 1 \quad (16)$$

and the most western column is

$$LX = \text{ABS}(\text{FLOAT}(\text{MOD}(\text{ISECT}-1,12)) - 5.5) + 1.6 \quad (17)$$

If JSECT is not present on the digitized record, the program assumes that no eastern columns and southern rows of the township are missing. Modification of Equations 16 and 17 provide the means to determine what columns or rows, or both, are absent. The number of the first southern row missing from a township is found by

$$LYY = (\text{JSECT} - 1) / 6 + 2 \quad (18)$$

and the first eastern column missing is

$$LXX = \text{ABS}(\text{FLOAT}(\text{MOD}(\text{JSECT}-1,12)) - 5.5) + 0.6 \quad (19)$$

Given the number of rows and columns in a township, the dimensions of all sections except those in the most northern row and the most western column are assumed to have equal widths and heights. The width of the section is

$$XDELTA = (\text{ABS}(X2 - X3)) / (LXX - LX - 1) \quad (20)$$

and the height is

$$YDELTA = (\text{ABS}(Y2 - X3)) / (LYY - LY - 1) \quad (21)$$

Many of the sections within a township have boundaries and corner points in common with other sections of the township. A full township contains 36 sections and thus has 49 uniquely located section corners. RAMP uses two 7-by-7 matrices to define the X and Y coordinates of the corner points. The X coordinate of the first two columns of the matrix (using standard matrix algebra notation) are

$$X_{1,1} = X1 \text{ and } X_{1,2} = X2 \quad (22), (23)$$

and for the remaining columns of the matrix are

$$X_{i,j} = X_{i,j-1} + XDELTA \quad (24)$$

in which, $LY \leq i \leq LLY-1$ and $LX+2 \leq j \leq LXX-1$.

In a similar manner, the coordinates of the first two rows of the Y matrix are

$$Y_{1,1} = Y1 \text{ and } Y_{1,2} = Y2 \quad (25), (26)$$

and for the remaining rows

$$Y_{i,j} = Y_{i,j-1} + YDELTA \quad (27)$$

in which $LY+2 \leq i \leq LLY-1$ and $LX < j < LXX-1$.

With all elements of the two coordinate matrices known, Equations 1 and 3 can then be used to develop the latitude and longitude of each section point.

The second method is used to map a quadrilateral section that has one 90-degree internal angle. The 90-degree angle is required in RAMP because of the hardware limitation of no more than three digitized points on a record. This angle is used as a reference point in the algorithm. Its coordinates are calculated from information gained in the digitization of the three other corners of the quadrilateral. A simpler algorithm can be developed which does not require the 90-degree internal angle when four points can be digitized per record. Moving clockwise from the reference point, the operator digitizes the first corner (referred to as X1 and Y1 here). Then he digitizes the next corner (known as X2 and Y2). And then he digitizes the last corner (called X3 and Y3) before returning to the reference point.

RAMP assumes that the right angle of the quadrilateral section is located at the origin of a rectangular system of axes. The quadrant which contains the section is found by logical analysis of the first and last points digitized. Thus

$$\begin{aligned} X3 > X1 \text{ and } Y1 > Y3 &= \text{Quadrant 1} \\ X3 > X1 \text{ and } Y1 < Y3 &= \text{Quadrant 2} \\ X3 < X1 \text{ and } Y1 < Y3 &= \text{Quadrant 3} \\ X3 < X1 \text{ and } Y1 > Y3 &= \text{Quadrant 4} \end{aligned}$$

For sections located in Quadrants 1 and 3, the coordinates of the origin are

$$X4 = X1 \text{ and } Y4 = Y3 \quad (28), (29)$$

and for Quadrants 2 and 4, the coordinates are:

$$X4 = X2 \text{ and } Y4 = Y1 \quad (30), (31)$$

A quadrilateral section containing one 90-degree internal angle can have two "basic" shapes (*fig. 2*). It is always possible to partition such a section into an oblique triangle and a right triangle. Location of the centroid in this section requires identifying a fifth point, called X5 and Y5. The coordinates of the unknown point are located on a straight line passing through the points X1, Y1 and X3, Y3. The equation of this line is

$$A * X5 + B * Y5 + C = 0 \quad (32)$$

in which

$$A = Y2 - Y3, B = X1 - X3 \quad (33), (34)$$

and

$$C = X3*Y1 - X1*Y3 \quad (35)$$

The point $X5, Y5$ is also a member of a straight line passing through point $X2, Y2$. By requiring this line to be perpendicular to Equation 32, the coordinates of the point $X5, Y5$ can be found by the following expression

$$X5 = (B*B*X2 - A*B*Y2 - A*C) / (A*A + B*B) \quad (36)$$

and

$$Y5 = (A*A*Y2 - A*B*X2 - B*C) / (A*A + B*B) \quad (37)$$

The centroid of the quadrilateral section can now be obtained by the use of the principle of moments (Higdon and others 1955). Logical check of the points $X5, Y5$ and $X2, Y2$, along with the quadrant position of the section will determine if the area of the oblique triangle, called $A2$, must be removed or added to the area of the right triangle ($A1$). Thus

$$\begin{aligned} \text{Quadrant 1 or 4, and } X2 < X5 &= -A2 \\ \text{Quadrant 2 or 3, and } X2 > X5 &= -A2 \end{aligned}$$

The moments of the areas around the X and Y axes for sections located in quadrants 1 or 3 are

$$XBAR = (A1*X3 + A2*(X3 + X2)) / (3.*(A1 + A2)) \quad (38)$$

and

$$YBAR = (A1*Y1 + A2*(Y1 + Y2)) / (3.*(A1 + A2)) \quad (39)$$

respectively. For sections located in quadrants 2 and 4, the moments of the areas around the X and Y axes are

$$XBAR = (A1*X1 + A2*(X1 + X2)) / (3.*(A1 + A2)) \quad (40)$$

and

$$YBAR = (A1*Y3 + A2*(Y3 + Y2)) / (3.*(A1 + A2)) \quad (41)$$

respectively. The intersection of the $XBAR$ and $YBAR$ is the location of the midpoint of the quadrilateral section, expressed in the rectangular coordinates of the digitizer. Equations 1 and 3 can be used to develop the latitude and longitude of corners of the section and its midpoint.

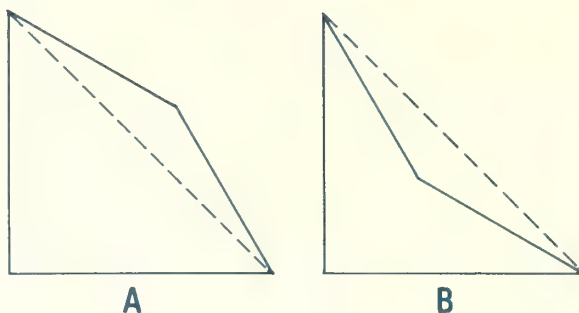


Figure 2—A quadrilateral section that contains an internal 90-degree angle can have two "basic" shapes. Dashed lines illustrate how the section can be viewed as an oblique triangle added (A) or subtracted (B) from a right triangle.

A modification of the above process is used to digitize a right-triangular section. In this situation, the third digitized point ($X3, Y3$) is the corner of the internal 90-degree angle. Equations 28 to 37 are not required in this situation. RAMP uses a logical comparison of the three digitized points to differentiate a right triangle from a quadrilateral section. Information on the quadrant position of the section will determine the equations to use for solution of $XBAR$ and $YBAR$. When $A2$ is given a zero value, Equations 38 to 41 are then applicable for locating the midpoint of the section.

The third method is used to map a single rectangular section. Only two digitized points are required. The problem is easily solved by RAMP.

APPLICATION

RAMP was designed originally to provide a useful spatial variable that could be associated with data from the Individual Fire Reports for the FOCUS program. FOCUS (Fire Operational Characteristics Using Simulation) is a model being developed at the Pacific Southwest Forest and Range Experiment Station's Forest Fire Laboratory, Riverside, California, to simulate the probable consequences of available alternatives in fire planning (Storey 1972). To date, a cross-reference catalogue has been produced within the computer for 12 National Forests and one California Division of Forestry Ranger Unit by RAMP.

The techniques and procedures used in RAMP can be applied by land-use planners to tap many other sources of useful spatial information. As an example, a brief investigation shows that it could be applied to the following U. S. Forest Service reports: (a) Bridge Inventory, R5-7700-24; (b) Report of Suspected

Timber Trespass, R5-6500-129; (c) Record of Sale, Land or Easement, R5-5400-11; (d) Animal Damage Survey, R5-5200-39; (e) Prescribed Burn Report, R5-5100-199; (f) Archaeological Site Survey Record, RS-2700-31; and (g) Tree Seed Crop Condition Report, R5-2400-58.

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Wildland Planning Glossary

Charles F. Schwarz Edward C. Thor Gary H. Elsner



PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
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1976. **Wildland planning glossary**. USDA Forest Serv. Gen Tech. Rep. PSW-13, 252 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

More than 1400 terms useful in wildland and related resource planning are defined. The purpose of the work is to facilitate communication between professionals, not to provide them with exhaustive vocabularies of each other's specialties. Definitions are drawn from many sources, including public laws and government manuals, but are not intended to establish legally binding definitions. A list of terms and list of sources are included.

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Retrieval Terms: wildland planning; land utilization; range management; forest management; terminology.

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To: The Readers

A primary goal of the Land Use Planning Unit is to establish a communications network among all planners and those interconnected with planning. There is a basic need for quick transfer of methodology and techniques to support an effective job of planning with a minimum of duplication and effort.

Good communications demand common agreement on the meanings of words. This is particularly true in scientific and professional disciplines, and especially critical where quantified techniques must be used. Agreement comes from understanding and acceptance over time.

This "Wildland Planning Glossary," prepared by the Pacific Southwest Forest and Range Experiment Station, is a good beginning towards obtaining common understanding and acceptance of the meanings of words. This glossary is the first edition in a series which will become even more comprehensive as new wildland planning terms and concepts are added. Many words, if not most, will be immediately understood and accepted by all who read it. Other words may cause controversy and not be accepted by some. Suggestions for improvement of meaning and additional terms should be addressed to:

Unit Leader
Systems Application Unit for
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3825 East Mulberry
Fort Collins, Colorado 50371

All readers are invited to participate by commenting on these meanings when they do not agree or understand. Comments or suggestions for improvement should provide references or justification for change. New editions incorporating suggested changes and additional terms and definitions will be prepared by the Systems Application Unit.

THOMAS C. NELSON
Deputy Chief

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Individual acknowledgment for the help received in shaping this glossary is not possible because so many people participated. For example, more than 50 people reviewed the first and second drafts, and a number of others made valuable contributions.

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Lake Tahoe Area Research Coordination Board.

Soil Conservation Society of America: Land Use Planning Subcommittee, Natural Vegetation Subcommittee, California Chapter Conservation Research Committee.

U.S. Department of Agriculture: Agricultural Research Service, Western Regional Office; Soil Conservation Service, California State Office.

U.S. Department of Agriculture, Forest Service: Resource Planning Act Team (WO); National Forest System—Land Use Planning Unit, Watershed and Minerals Management Staff (WO), Regional Office Land Use and Multiple Use Planning Units; State and Private Forestry Area Planning and Development Staff (WO) (Comprehensive Land Use Planning Group and Cooperative Planning and Rural Development Group); Research Forest Economics and Marketing Research Staff (WO), Intermountain Forest and Range Experiment Station Surface Environment and Mining Team (SEAM), Pacific Southwest Forest and Range Experiment Station.

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PREFACE

National recognition of the importance of land use planning in the management of the Nation's wildlands is growing steadily. Many local and State governments have already passed land use planning laws. The Federal Government, in stages marked by the passage of the National Environmental Policy Act of 1969 and the Coastal Zone Management Act of 1972, has been gradually moving toward comprehensive land use planning, and a national land use planning act will probably be passed before long. The U.S. Forest Service has already adopted land use planning procedures for management of all National Forests.

Such growth, as might be expected, has been attended by problems of communication—coordination, definition, and exchange of information. Wildland planning has brought together the wildland manager (usually trained in forestry or range management), the professional planner (usually trained in city or regional planning), and specialists in any of a dozen or more natural, physical, or social sciences. Most of these people have only limited knowledge of the concerns, methods, and terminology of special fields other than their own.

In the absence of a standard reference work, the terminology of wildland planning has become a haphazard accumulation of technical terms—many duplicating others in meaning, many used differently by different people, and some having no precise meaning at all. Obviously, such terminology can only aggravate the difficulties of communication.

This book is an attempt to alleviate the problem by providing definitions of the terms currently used in wildland planning. The purpose here is to facilitate communication between professionals, not to supply them with exhaustive vocabularies of each other's specialties. Accordingly, only those terms of each discipline that are most important to wildland planning are listed. Less frequently used terms may be found in glossaries of special fields. Many such works are listed here under Sources.

We do not present this book as a final product. Just as the rapid growth of wildland planning has made the glossary necessary, so continued growth will make it obsolete; new terms will be developed and some of those given here will drop out of use. A glossary, though giving temporary stability and unity to terminology, should not cause stagnation. Our hope is that this first effort will be followed by expanded and revised editions, keeping pace with the evolution of wildland planning, and thus contributing to it.

The forms of entry and definition used in this book vary somewhat from those of standard dictionaries and glossaries.

Alphabetizing. All entries are listed in strict alphabetical order, regardless of word breaks. For example, **Mine tailings** follows **Mineral soil** and precedes **Mining, area strip**. However, clusters of multiple-word terms are entered under the main word: for example, **Erosion, accelerated** and **Erosion, raindrop** follow **Erosion**.

Synonyms. Where several similar terms for one concept are in use, or where various terms are used interchangeably with a variety of meanings (sometimes contradictory), the main entry is the preferred or standard term. Preference is usually determined as the original or apparently most common usage. Less acceptable terms follow the main entry in parentheses. The terms in parentheses are not necessarily accurate synonyms for the main entry.

Boldface terms. A boldface term within a definition is being used precisely and is itself defined in the glossary.

Sources. The definitions given come from many sources, including public laws or Government manuals. We have made no attempt, however, to establish legally binding definitions or official doctrine. Some officially stated definitions are not in agreement with common usage, but they are included because planners often need to be aware of them.

Each definition is followed by an abbreviated source citation in parentheses; complete citations are listed at the end of the book. Definitions followed only by initials are those originated for this glossary by one of the authors or by a reviewer.

List of terms. A simple listing of all terms included precedes the glossary. This list allows the user to determine quickly the form of the main entry for the particular term needed. It can also serve as a thesaurus of terms for the writer who is groping for the right word.

LIST OF TERMS

- Abiotic
Abiotic commodity
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- MU-SY. *See* Multiple Use-Sustained Yield Act
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- National Ambient Air Quality Standards
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- National Forest land use plan. *See* Forest land use plan
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- National Land Use Policy Act. *See* Land Use Policy and Planning Assistance Act
- National Natural Landmark, *See* National Registry of Natural Landmarks
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- National Trails System Act
- Native grazing land. *See* Grazing land, native
- Native organism
- Native pasture. *See* Pasture, native
- Native pasture land. *See* Pasture, native
- Native species. *See* Native organism
- Natural
- Natural Area. *See* Natural Area Preserve and Natural Area, Research
- Natural Area Preserve
- Natural Area, Research
- Natural capability. *See* Capability
- Natural carrying capacity. *See* Carrying capacity, ecological
- Natural erosion. *See* Erosion, natural
- Natural hazard
- Natural hazard lands
- Natural history resource
- Naturalized species. *See* Species, naturalized
- Natural law. *See* Law, natural
- Natural preserve. *See* Natural Area Preserve and Natural Area, Research
- Natural region. *See* Region, natural
- Natural Reserve. *See* Natural Area Preserve and Natural Area, Research
- Natural resource
- Natural resource district. *See* Soil conservation district
- Natural resource zoning. *See* Zoning, natural resource
- Natural vegetation
- Nature Preserve. *See* Natural Area Preserve and Natural Area, Research
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- Negative easement. *See* Easement, negative
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- New study area. *See* Wilderness study area
- New wilderness study area. *See* Wilderness study area

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 Noncontinuous easement. *See* Easement, discontinuous
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 Panoramic landscape. *See* landscape, panoramic
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 Parent material
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- Perched groundwater table. *See* Water table, perched
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- Percolation
- Perennial stream
- Performance standard zoning. *See* Zoning, performance
- Performance zoning. *See* Zoning, performance
- Periodic allowable cut. *See* Allowable cut (2)
- Periodic allowable yield. *See* Allowable cut (2)
- Periodic cut. *See* Allowable cut (2)
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- Peripheral species. *See* Species, peripheral
- Permanent pasture
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- Permeability
- Permissible cut. *See* Allowable cut (2)
- Permissible soil loss. *See* Soil-loss tolerance
- Permissible yield. *See* Allowable cut (2)
- Persistent pesticides
- Personal distance. *See* Individual distance
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- Perspective
- Perspective, aerial
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- PERT
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- Phreatophyte
- Physical carrying capacity. *See* Ecologic carrying capacity (5)
- Physical life
- Physical planning
- Physiographic
- Physiographic climax. *See* Climax community (3)
- Physiographic determinism
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- Physiographic province. *See* Region, physiographic
- Physiographic region. *See* Region, physiographic
- Physiographic site class
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- Phytoplankton. *See* plankton
- Pit mining. *See* Mining, pit
- Pitting
- Placer claim
- Placer mining. *See* Mining, placer
- Plan
- Plan controls
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- Planimetric map. *See* Map, planimetric
- Plankton
- Planned grazing system
- Planned unit development. *See* Cluster development
- Planned unit development zoning. *See* Zoning, cluster
- Planner
- Planning
- Planning agent
- Planning, anticipatory
- Planning area
- Planning area guide
- Planning horizon
- Planning level
- Planning process. *See* Planning (1)
- Planning-Programming-Budgeting System
- Planning unit
- Plan objective. *See* Objective
- Plan selection
- Plant association. *See* Plant community
- Plant community
- Plant cover type. *See* Cover type
- Plant retrogression
- Plant succession. *See* Succession
- Plat
- Pluralism
- Pluralistic society
- Plutonic rock. *See* Rock, igneous (1)
- Point pollution source. *See* Point source pollution
- Point source pollution
- Police power
- Policy
- Policy plan
- Political boundary
- Political determinism
- Political institutions
- Pollution

Pollution criteria. *See* Criteria
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 Positive feedback. *See* Feedback loop
 Possibly extinct species. *See* Species,
 recently extinct or possibly extinct
 Potential. *See* Biotic potential
 Poverty, absolute
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 PPBS. *See* Planning-Programming-
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 Pre-existing use. *See* Use, pre-existing
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 Premature grazing. *See* Grazing, premature
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- Range management
- Range, open
- Range, planning. *See* Range management
- Range, primary
- Ranger District multiple use plan
- Range readiness
- Range, secondary
- Range site
- Range suitability
- Range, suitable
- Range, transitory
- Range, unsuitable
- Range use. *See* Use, degree of
- Rare and Endangered Species Act. *See*
Endangered Species Act of 1973
- Rare species. *See* Species, rare
- RAU. *See* Resource analysis unit
- Raw land
- RCD. *See* Soil conservation district
- RCU. *See* Resource capability unit
- Recently extinct species. *See* Species,
recently extinct or possibly extinct
- Recharge
- Reclamation
- Reclamation, effective
- Reconnaissance soil map. *See* Soil
map, reconnaissance
- Reconnaissance soil survey. *See* Soil map,
reconnaissance and Soil survey
- Reconnaissance survey
- Recreation
- Recreational easement
- Recreational experience levels
- Recreational experience quality
- Recreational quality
- Recreational river area
- Recreation and park planning
- Recreation area, developed
- Recreation, concentrated
- Recreation day
- Recreation, dispersed
- Recreation, extensive
- Recreation, intensive
- Recreation land
- Recreation, primitive
- Recreation resource
- Recursive
- Reducer organism. *See* Decomposer
organism
- Reforestation
- Refuse. *See* Mining refuse
- Regeneration
- Regeneration cutting
- Region
- Regional climate
- Regional economic development
- Regional plan
- Regional planning
- Region, morphogenetic
- Region, morphological
- Region, natural
- Region, physiographic
- Register of National Natural Landmarks.
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Landmarks
- Regolith
- Regulatory standard. *See* Standard
- Relative poverty. *See* Poverty, relative
- Release cutting
- Relic
- Relict
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- Remote sensing
- Removal cutting
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- Renewable resource
- Renewable resource assessment. *See*
Forest and Rangeland Renewable
Resources Planning Act of 1974
- Renewable resource lands
- Renewable resource program. *See* Forest
and Rangeland Renewable Resources
Planning Act of 1974
- Reproductive capacity. *See* Biotic
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- Reproductive potential. *See* Biotic
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- Research Natural Area. *See* Natural
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- Reservation and other tribal lands
- Reservoir Salvage Act
- Residential density
- Residential land
- Resident species. *See* Species, resident
- Resource
- Resource allocation
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- Resource area. *See* Land resource area
- Resource bearing capacity. *See* Carrying
capacity, ecological

Resource capability unit. *See* Ecological land unit (2)

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Resource depletion. *See* Depletion

Resource, extrinsic. *See* Extrinsic resource

Resource, intrinsic. *See* Intrinsic resource

Resource Management System

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Resource scarcity. *See* Economic scarcity

Resources Planning Act. *See* Forest and Rangeland Renewable Resources Planning Act

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Riparian rights

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River basin plan

River basin planning

Roadless and undeveloped areas

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Rock, plutonic. *See* Rock, igneous (1)

Rock, sedimentary

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Rotation grazing. *See* Grazing, rotation

Rotation pasture. *See* Pasture, rotation

RPA. *See* Forest and Rangeland Renewable Resources Planning Act

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Sacrifice area

Sacrifice site

Salvage cutting

Sand

Sanitary landfill

Sanitation cutting

Sapling

Satisficing

Scale

Scarcity. *See* Economic scarcity

SCD. *See* Soil conservation district

Scenario

Scenic area

Scenic corridor

Scenic easement. *See* Easement, scenic

Scenic river

Schematic diagram. *See* Diagrammatic representation

SCS

Secondary effect. *See* Indirect effect

Secondary facility

Secondary range

Secondary sewage treatment. *See* Secondary wastewater treatment

Secondary succession. *See* Succession, secondary

Secondary treatment. *See* Secondary wastewater treatment

Secondary use

Secondary wastewater treatment

Second growth

Sediment-

Sedimentary rock. *See* Rock, sedimentary

Sediment discharge

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Seed tree

Seed tree cutting

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Seismic

Seismic hazards

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Selection logging

Selection system

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- Selective logging. *See* Selection logging
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- Sense of scale
- Sensitivity analysis
- Sensitivity, land
- Sensitivity level. *For U.S. Forest Serv. usage see* Visual sensitivity level
- Seral
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- Sheet erosion. *See* Erosion, sheet
- Sheet flow. *See* Overland flow
- Shelterwood cutting
- Shelterwood system
- Short-range planning
- Shrink-swell potential
- Silt
- Silvics
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- Simulation
- Sink
- Site
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- Site index
- Site plan
- Site planning
- Site quality
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- Skyline logging. *See* Logging, skyline
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- Slash
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- Snowslide. *See* Snow avalanche
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- Social carrying capacity. *See* Carrying capacity, psychological
- Social class
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- Social equity
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- Social institutions. *See* Institutions, social
- Social mobility
- Social mores
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- Social planning. *See* Advocacy planning
- Social power
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- Social primacy. *See* Social determinism
- Social role
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- Soft pesticides. *See* Nonpersistent pesticides
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- Soil and water conservation district. *See* Soil conservation district
- Soil association
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- Soil conservation district
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- Soil family
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- Soil horizon
- Soil liquefaction
- Soil loss equation
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- Soil map
- Soil map, detailed
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Soil map, reconnaissance
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 Soil region
 Soil resource inventory. *See* Soil survey
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 Species, feral
 Species, game
 Species, indigenous
 Species, introduced
 Species, keystone
 Species, local
 Species, native
 Species, naturalized
 Species, peripheral
 Species, rare
 Species, recently extinct or
 possibly extinct
 Species, resident
 Species, status undetermined
 Species, threatened
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 Splash erosion. *See* Erosion, splash
 Spoil bank
 Spoils. *See* Mining spoils
 Spot grazing
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 Standard Metropolitan Statistical Area
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 Suitability, inherent. *See* Capability
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- Surface erosion. *See* Erosion, surface
- Surface mining. *See* Mining, surface
- Surface restoration. *See* Reclamation
- Surface rights
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- Suspended load
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- Sustained production. *See* Sustained yield
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- Sweet spoils. *For mining usage see* Mining debris, sweet
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- System planning. *See* Functional planning
- Systems analysis
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- Taxonomy
- Technological assessment
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- Temporary license. *See* Temporary permit
- Temporary pasture. *See* Pasture, supplemental
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- Term permit
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- Territoriality
- Tertiary facility
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- T factor. *For Soil-erosion-related usages see* Soil loss tolerance
- Thermal enrichment. *See* Thermal pollution
- Thermal pollution
- Thinning
- Thixotrophy. *See* Soil liquefaction
- Threatened species. *See* Species, threatened
- Threshold level
- Timber management compartment
- Timber planning
- Timber Resource System
- Timber type. *See* Cover type (1)
- Time zoning. *See* Zoning, time
- TL_m. *See* Median tolerance limit
- Tolerance
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- Topsoil
- Tractor logging. *See* Logging, tractor
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- Traffic classification. *See* Traffic composition
- Traffic composition
- Traffic volume
- Trampling
- Transitory range. *See* Range, transitory
- Transportation network
- Transportation planning
- Transportation services land
- Travel influence zone
- Trophic level
- Turbidity
- Type conversion
- Unavailable forage
- Unacceptable risk. *See* Risk, unacceptable
- Uncertainty
- Underprivileged groups. *See* Disadvantaged groups
- Understocking
- Understory
- Undesirable species
- Undeveloped land
- Uneven-age management
- Uneven-age silviculture. *See* Uneven-age management
- Uneven-aged stand
- Unique resource
- Unique species. *See* Species, unique
- Unit. *See* Planning unit
- Unit plan
- Unit planning

Universal soil loss equation. *See* Soil loss equation
 Unpalatable species
 Unsuitable range. *See* Range, unsuitable
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 Urbanized area
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 Use, allowable
 Use capability
 Use, degree of
 Use district
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 Use, full
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 Use, over-
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 Utility
 Utility theory
 Utilization. *See* Use
 Util. *See* Utility theory
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 Value, amenity. *See* Amenity
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 Vegetation type
 Veto group
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 View landscape
 Virgin forest
 Visible area
 Visitor carrying capacity. *See* Carrying capacity, economic recreation

Visitor day
 Visual character subtype
 Visual character type
 Visual landscape. *See* View landscape
 Visual landscape character
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 Visual resource
 Visual subtype. *For* U.S. Forest Serv. usage *see* Visual character subtype
 Visual sensitivity level
 Visual variety class
 Visual vulnerability
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 Weeding. *See* Weed cutting
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 Wetlands
 Wet meadow
 Wild and Scenic Rivers Act
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 Wilderness area. *See* Wilderness (2)
 Wilderness study area
 Wildfire
 Wildland
 Wildlife
 Wildlife and Fish Habitat System
 Wildlife land
 Wild river area
 Willingness-to-pay
 Windfall
 Windfirm
 Windthrow
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 Working circle
 Working group

Working plan	Zoning, exclusive use
WRC	Zoning, flood plain
Xeric	Zoning, forest
Xerosere. <i>See</i> Succession (1)	Zoning, land capability
X section. <i>See</i> Cross section	Zoning, large-lot
Yarding	Zoning, natural resource
Yarding, skyline	Zoning, open space
Zonal soil. <i>See</i> Soil horizon (2)	Zoning ordinance
Zoning	Zoning, performance
Zoning, aesthetic	Zoning, prohibition
Zoning, agricultural	Zoning permit
Zoning, cluster	Zoning, spot
Zoning, conservation	Zoning, time
Zoning, development	Zoning variance. <i>See</i> Variance
Zoning, Euclidean	Zoological area
	Zooplankton. <i>See</i> Plankton

Abiotic

The nonliving, material (as opposed to conceptual) components of the environment such as air, rocks, soil (in general), water, coal, peat, plant litter, etc. (*C.F.S.*)

Abiotic commodity

A broad class of resource products which includes all material yields of commercial value whose initial condition was that of a nonliving substance—such as water, steam, minerals, sand, gravel, petroleum, and natural gas. (*C.F.S.*)

Abiotic productivity. See **Productivity, abiotic.**

Absentee ownership

The holding of property by a person or persons not living or working on the premises and not regularly present to oversee its use or maintenance. (*Abrams, 1971*)

Absolute poverty. See **Poverty, absolute.**

Accelerated erosion. See **Erosion, accelerated.**

Acceptable material

Mining reclamation usage. Any soil material within the waste materials overlying a mineral deposit to be removed by surface mining which (based on soil fertility evaluation and other tests) possesses (or can be readily modified to possess) chemical and physical properties making it a satisfactory medium for growth of plants common in the area. (*Counc. Agric. Sci. Technol. 1973*)

Acceptable risk. See **Risk, acceptable.**

Acceptability test

U.S. Water Resources Council (WRC) usage. One of the tests to be applied in choosing among alternatives in planning for water and related land

resources while following the WRC principles and standards.

The "acceptability test" refers to the workability and viability of the plan in the sense of acceptance by the public and compatibility within known constraints. (*U.S. Dep. Agric. 1974*)

Accessibility

1. The relative ease or difficulty of getting to or from someplace. For example, a potential land use evaluation procedure may locate areas with characteristics highly favorable for use but which are separated from the nearest road by some impediment to travel—such as bluffs or a river. Such an area would be characterized as having low accessibility. (*C.F.S.*)

2. Range management usage. The ease with which animals penetrate and graze an area. (*Amer. Soc. Range Manage. 1964*)

Accessory use. See **Secondary use.**

Acculturation

The processes and results of contact between two or more different cultures.

Generally, acculturation brings about considerable diffusion of cultural traits in one or more directions. However, other change-processes also occur, such as development of new intercultural roles, the growth of new customs not found in either culture and the disintegration of older cultural forms. (*O'Connell 1974*)

Acquisition of development rights. See **Development rights, acquisition of.**

Acquisition of land

Purchase of full land ownership rights. (*C.F.S.*)

Also see **Property rights.**

Acre-foot

A water or sediment volume measurement term, equal to the amount of water which would cover an area of one acre to a depth of one foot—i.e., 43,560 cubic feet or 325,851 gallons. (*E.C.T.*)

Action plan. See **Activity planning**.

Active fault. See **Fault, active**.

Activity planning (Functional planning)

U.S. Forest Service usage. Under the "multiple use planning" system "activity planning" referred to the functional plans for such items as timber management, recreation, transportation and fire protection. (*U.S. Forest Serv., FSM 2111.9, Sept. 1972*)

Under the newly adopted "land use planning" system, activity plans are called "functional plans". (*U.S. Forest Serv., FSM 8213, Oct. 1973*)

Also see **Functional planning**.

Adaptive planning (Contingency planning)

A planning strategy whereby planning efforts are directed toward meeting temporary crises which arise in response to changing conditions. The planner responds to external forces influencing the area, identifies potential and current crises, takes advantage of externally developed resources (such as a new Federal program), and attempts to forestall or solve the crises by creating the proper response to the pressures generated by those forces. (*After Bolan 1967*)

Additive weighting

Decisionmaking method whereby a number of very different kinds of potential resource yields (whose values can not be directly compared by conversion to common units of measurement, such as dollars) are assigned numerical values on the basis of some more or less objective, common-sense notion of their relative importance. The simple summation of the

weightings of alternative resource yield mixes is used as the basis for making choices.

Maximization of the net social yield of resource use is either the mix which maximizes the sum of the additive weights, if numerically larger weights are assigned to more important values or minimizes the sum, if relative importance values are assigned on the basis of rankings, with 1 being the most important type of yield and successively less important yields being assigned higher numbers. (*C.F.S.*)

Administration

Execution of an organizational policy to reach predetermined objectives (*U.S. Forest Serv. 1971*)

Administrative unit

U.S. Forest Service usage. An area under the administration of one line officer. Examples include the Forest Service California Region, a National Forest, and a Ranger District.

This term includes a single National Forest or National Grassland or portion thereof, or a Ranger District or separate portion thereof. (*U.S. Forest Serv., FSM 2624.3, Sept., 1970*)

ADT. See **Average daily traffic**.

Adversary procedure

Involving the Anglo-American system of procedure for conducting civil trials under strict rules of evidence with the right of cross examination and argument, one contestant with his witnesses striving to prove the facts essential to his case and the other striving to disprove those facts or to establish an affirmative defense. (*Webster 1963*)

This procedure is sometimes advocated as a best method for resolving (in or out of court) land use planning issues having or involving readily identified, opposing, antagonistic parties or interests.

Its theoretical strength lies in the strong presentation and contrasting of both pro and con interpretations of what the real facts are for the judging parties. Its theoretical weaknesses lie in the distortions of the relative merits of the opposing cases that may result from unequal (1) ability to finance presentations and defenses, (2) access to information, (3) theatrical and intellectual abilities in making presentations and cross examinations and, (4) limits on the ability of judging parties to be truly objective. (*C.F.S.*)

Adverse land use

1. Not in conformity with the planning or social requirements of the community. (*U.S. Bur. Outdoor Recreation 1974*)

2. Use of land which results in soil erosion rates greater than the soil-loss tolerance values (which have been established by use of the soil loss equation). (*After W.A.B.*)

Advocacy planning

1. The practice of professional planners voluntarily helping underprivileged sections of society to give expression to their hopes for a better environment. (*Ashworth 1973*)

2. More generally used in the sense of planners working directly with socio-economically defined special interest groups to translate their aspirations for a living environment into formal planning goals and a set of procedures for attaining those goals. Presumably conflicts between different socioeconomic groups' values are to be resolved by adversary procedures during which the arguments for and against all proposals are presented. (*C.F.S.*)

Aerial logging. See Logging, aerial.

Aerial perspective. See Perspective, aerial.

Aesthetic recreational carrying capacity. See Carrying capacity, wildland recreation, definition 5.

Aesthetics

1. Evaluations and considerations concerned with the sensory quality of resources (sight, sound, smell, taste and touch) and especially with respect to judgment about their pleasurable qualities. (*C.F.S.*)

2. Pertaining to the quality of human perceptual experience (including sight, sound, smell, touch, taste, and movement) evoked by phenomena or elements or configurations of elements in the environment. (*L.W.*)

Aesthetic zoning. See Zoning, aesthetic.

Affirmative easement. See Easement, affirmative.

Afforestation

The establishment of a tree crop on an area from which it has always or very long been absent. (*Ford-Robertson 1971*)

Agricultural land

Land used primarily for the production of farm commodities.

The categories of "agricultural land" are: cropland and pasture; orchards, groves, vineyards, bush fruits, and horticultural areas (such as nurseries); feeding operations; and other. (*Anderson, et al. 1972*)

Agricultural zoning. See Zoning, agricultural.

Agriculture

1. A broad class of resource uses which includes all forms of land uses for the production of biotic crops—whether animal or plant.

Where large amounts of wildlands are contained in planning units it is useful to subdivide agriculture in its broadest sense into subcategories which make a distinction between harvesting where little or no management inputs are made to increase natural biotic productivity (as in wildland range, most timber, fish and wildlife harvesting uses) and a subcategory

which includes all desirable biotic productivity which has been significantly increased over natural rates by management inputs—including such uses as cultivated and/or irrigated farming and managed pasture. (*C.F.S.*)

2. The use of the land for agricultural purposes, including farming, dairying, pasturage, agriculture, apiaries, horticulture, floriculture, viticulture, and animal and poultry husbandry, and the necessary accessory uses for packing, processing, treating or storing the produce; provided, however, that the operation of any such accessory uses shall be secondary to that of normal agricultural activities and provided further that the above uses shall not include the commercial feeding of garbage or offal to swine or other animals. (*Eisner 1969*)

Air pollution

Any substance or energy form (heat, light, noise, etc.) which alters the state of the air from what would naturally occur.

Especially associated with those altered states whose physical, chemical, biological, psychological or aesthetic impacts have been decreed to be undesirable by human value judgments. (*E.C.T.*)

Air rights

The right to the use of air space over property owned by another.

Air rights can be sold or leased. Through the erection of a platform over the existing use, additional "land" can, in effect, be created. (*Abrams 1971*)

Air shed

1. A region with common sources and problems of air pollution; it may coincide with a watershed or be a part of a large urban agglomeration. (*Durrenberger 1973*)

2. The air encompassing a specific geographic region.

Although not as well defined, this concept is comparable to a watershed. (*Sesco, et al. 1973*)

Algal bloom (Bloom, Water bloom)

A readily visible, high concentration of algal growth or aggregation of algae in or on the surface layer of a body of water. (*Sesco, et al. 1973*)

Alienated land. See Land, alienated.

All-aged stand. See Uneven-aged stand.

Allocation. See Resource allocation and Land use allocation.

Allotment. For range management usage see Range allotment.

Allowable cut (Prescribed cut, Prescribed yield, Permissible yield, Allowable harvest)

1. The volume of timber which can be cut, under specified management plans during a given period. (*Sesco, et al. 1973*)

2. The amount of forest productivity that may be harvested, annually or periodically, from a specified area over a stated period, in accordance with the objectives of management.

For timber productivity "allowable cut" is usually stated in terms of wood volume, number of stems of certain size categories or area that can be cut over.

When "allowable cut" is expressed as the amount that can be removed on an annual basis it is termed "annual (allowable) cut" or "annual (allowable) yield". When expressed as the amount that can be removed at recurring time periods of greater than a year it is termed "periodic (allowable) cut" or "periodic (allowable) yield". The amount actually prescribed to be cut is termed the "prescribed yield", "prescribed cut", "permissible yield" or "permissible cut". (*After Ford Robertson 1971*)

The common usage of all these terms carries with it an implicit conno-

tation of an overall rate of harvesting which is in dynamic balance with the ability of the forest to replace what has been removed with new wood growth. (*C.F.S.*)

Allowable harvest. See **Allowable cut.**

Allowable use. For range management usage see **Use, allowable.**

Alluvial

Pertaining to material that is transported and deposited by running water. (*Soil Conserv. Soc. Amer. 1970*)

Alluvial land

1. An area of unconsolidated **alluvium**, generally stratified and varying widely in texture, 'recently' deposited by streams and subject to frequent flooding. (*Soil Conserv. Soc. Amer. 1970*)

2. U.S. Soil Conservation Service usage. A miscellaneous land type in the U.S. Soil Conservation Service Land Classification System characterized by the deposits and processes given in definition 1. (*C.F.S.*)

Alluvial valley floor

The unconsolidated stream-laid deposits holding streams where water availability is sufficient for subirrigation or flood irrigation agricultural activities. (*Surface Mining Control and Reclamation Act of 1975*)

Alluvium

Material, including clay, silt, sand, gravel and mud, deposited in riverbeds, lakes, **alluvial fans**, valleys and elsewhere by modern streams. (*Durrenberger 1973*)

Alternate grazing. See **Grazing, rotation.**

Alternative

The different means by which objectives or goals can be attained.

They need not be obvious substitutes for one another or perform the same specific function. (*U.S. Forest Serv. 1972B*)

Alternative futures. See **Futures.**

Alternative life styles. See **Life styles.**

Ambient

1. Referring to surrounding, external or unconfined conditions. (*C.F.S.*)

2. Referring to the quality of some specific environmental factor—such as the "ambient" temperature or "ambient" air pollution levels. (*C.F.S.*)

Amenity (Amenity value)

1. An object, feature, quality, or experience that gives pleasure or is pleasing to the mind or senses. (*After Webster 1963*)

2. The pleasurable or aesthetic, as contrasted with the utilitarian, features of a plan, project, location or resource.

The term amenity is now used so broadly that it can refer to just about anything that makes life more agreeable—from a temperate climate to an intellectual climate. (*Abrams 1971*)

3. (Amenity value.) Typically used in land use planning to describe those resource properties for which **market values** (or **proxy values**) are not or cannot be established. (*E.C.T.*)

Anadromous fish

Those species of fish which mature in the sea, and migrate into streams to spawn. Salmon, steelhead, and shad are examples. (*U.S. Forest Serv. 1963. FSM 2605, Sept. 1974*)

Analysis

1. A detailed examination of anything complex in order to understand its nature or determine its essential features. (*Webster 1963*)

2. A separating or breaking up of any whole into its component parts for the purpose of examining their nature, function, relationship, etc. (*Webster 1963*)

3. In mathematics and computer science, it pertains to solving problems. (*U.S. Forest Serv. 1972B*)

Angle of repose (Critical slope)

1. The angle between the horizontal and the maximum slope that a soil or loose rock fragments assumes through natural processes. (*Soil Conserv. Soc. Amer. 1970*)

2. The maximum slope or angle at which a material, such as soil or loose rock, remains stable. (*Amer. Geol. Inst. 1962*)

Animal community. See **Biotic community.**

Animal month

A month's tenure upon range by one animal. (*Amer. Soc. Range Manage. 1964*)

Animal unit conversion factor

A numerical grazing measurement figure which allows conversion from one kind or class of animal to another.

Such a conversion factor is satisfactory in respect to the amount of forage required to maintain an animal, but may have no application in determining stocking rates for range use for particular kinds or classes.

Conversion factors generally accepted are: mature cow with calf, 1.0; mature bull, 1.25; weaned calf, 0.6; yearling over 12 months and under 17 months, 0.7; yearling from 17 to 22 months, 0.75; two-year old from 22 to 32 months, 0.9; elk, 0.7; white-tail deer, 0.14; mule deer, 0.2; mature ewe with lamb, 0.2; ram, 0.2; weaned wether, 0.17; doe goat with kid, 0.17; buck, 0.17; weaned wether, 0.14 and grown horse, 1.25. (*Amer. Soc. Range Manage. 1964*)

Animal unit month (AUM)

The quantity of forage required by one mature cow (1000 lbs) or the equivalent for one month. (*Dyrland 1973*)

Annual cut. See **Allowable cut**, definition 2.

Annual flood. See **Flood**, annual.

Annual pasture. See **Pasture**, annual.

Annual range. See **Range**, annual.

Annual yield (Annual allowable yield).
See **Allowable cut**, definition 2.

Antagonism

The combined action of two or more agents that is less than the sum of the actions of each of the agents acting separately or independently. (*Webster 1963*)

See **Synergism** for combined actions which are greater than a simple summation of individual actions.

Antecedent moisture (Antecedent soil water)

The degree of wetness of the soil at the beginning of a runoff period, expressed as an index or as the total inch-depth-equivalents of water stored in the soil. (*Soil Conserv. Soc. Amer. 1970*)

Antiquities Act (34 Stat. 225)

The Antiquities Act of 1906 provides for the protection of historic or prehistoric remains, or any object of antiquity, on Federal lands; establishes criminal sanctions for unauthorized destruction or appropriation of antiquities and authorizes scientific investigation of antiquities on Federal lands, subject to permit and regulations. (*U.S. Forest Serv., FSM 2361.01, Feb., 1974*)

Approximate original contour. See **Contour**, approximate original.

Aquifer

A geologic formation or structure that transmits water in sufficient quantity to supply the needs for a water development, such as a well.

The term "water-bearing" is sometimes used synonymously with "aquifer" when a stratum furnishes water for a specific use.

Aquifers are usually saturated sands, gravel, fractured rock, or cavernous and vesicular rock. (*Soil Conserv. Soc. Amer. 1970*)

Archeological area

U.S. Forest Service usage. Sites and areas which have been designated by the Forest Service as containing important evidence and remains of the life of man on earth between the time of his first appearance and the development of written history.

Archeological remains are the sole kind of evidence that applies to prehistory and provides information about all aspects of human life throughout this period. (*After U.S. Forest Serv., FSM 2361.21, July, 1973*)

Areas of this type and all other special interest areas are identified and formally classified primarily because of their recreational values. (*W.W.*)

Archeological resource

The subclass of cultural history resource planning considerations which includes all remaining physical evidence of former occupation by now extinct cultural groups—including skeletons, settlement remains, implements, artifacts, monuments and inscriptions.

In the United States this subclass is most easily distinguished from its more recent counterpart “historical resources” by establishing a dividing point in time between the two at the beginning of movement of settlers into an area.

This resource class does not include any of the more recent physical products of contemporary native cultural groups such as may exist on Indian reservations. (*C.F.S.*)

area guide. For U.S. Forest Service usage see Planning area guide.

Area of critical environmental concern (Critical area)

Usage in the defeated 1973 bill for a National Land Use Policy and Planning Assistance Act.

Areas, as defined and designated by states on non-Federal lands, where un-

controlled or incompatible development could result in significant damage to the environment, life or property, or the long term public interest which is of more than local significance.

Three specific classes of critical areas are defined in the Act— **fragile or historic lands, natural hazard lands, and renewable resource lands**. States may also add additional types of areas of critical concern.

Coastal areas are specifically deleted from the definitions of the types of areas of critical environmental concern. In an amendment relating the **Coastal Zone Management Act** to this Act the words “coastal wetlands, marshes, and other lands inundated by the tides, beaches, dunes and significant estuaries” were deleted from the definition of fragile or historic lands. A state is free to add these areas to its state land use program. However, the state need not do so, but rather can keep such areas separate and accountable only to the requirements of the Coastal Zone Management Act.

The Land Use Policy and Planning Assistance Act did not require the Federal government to designate such areas on Federal land. Areas of critical environmental concern are to be designated only on private, state and Indian lands.

These definitions were purposely left legally incomplete, in accordance with the purpose of the Act, to improve the states’ ability to devise and implement their own land use policies. By further refining these definitions the states make the first basic policy decisions concerning the scope and the thrust of the state land use programs. For example, major policy decisions are involved in determining what is a “shoreline”. Is it a shoreline of all bodies of water or only bodies of a certain size? Is it limited to relatively undeveloped shoreline? Is its extent

four hundred feet inland of the water, four hundred yards, or to the extent of any land the use of which has a direct impact on the water? What are "major recreational lands and facilities"? What are "issues of more than local significance" in the judgment of the state?

This category is not designed to be a "no growth" category. Only uncontrolled development is unwanted. The adjective "incompatible" is present to make certain that development is to be allowed which is compatible with the basic environmental or renewable resources values or safety problems of the land in question. Multiple use, when planned, is clearly expected. The category "Areas of critical environmental concern" has been subdivided into subcategories to pinpoint the basic values of the land involved so as to better provide opportunities for development which can demonstrate its compatibility with such values. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Area planning. See **Regional planning and Planning area.**

Area reconnaissance

Engineering and surveying usage. The projection of feasible road routes on an area topographic map and their delineation on aerial photographs. (*U.S. Forest Serv., FSH 7140, 1973*)

Area strip mining. See **Mining, area surface.**

Area surface mining. See **Mining, area surface.**

Aspect (Exposure, Slope orientation)

The compass direction that the slope of a land surface faces toward (e.g., north, northwest, south). (*After Soil Conserv. Soc. Amer. 1970*)

Association. See **Biotic community.**

Assumption (Basic assumption, General assumption)

1. Something that is taken for granted or accepted as true. (*After Webster 1963*)

2. A judgmental decision by planners which supplies missing values, relationships or societal preferences for some informational component necessary for making a decision.

The true nature of such missing information is either unknown or cannot be readily ascertained within the time and/or budgetary constraints on the need for the planning decision. (*C.F.S.*)

Attitude

1. A learned predisposition manifesting itself in a general state of readiness either to evaluate or to react toward an object or class of objects in either a favorable or unfavorable manner in a more or less consistent and characteristic way.

Attitudes are relatively stable and are comprised of three components: a cognitive or belief component, an affective or feeling component, and a conative or action-disposition component.

Although behavior may be a function of attitude at times, attitudes are not necessarily predictors of behavior under all circumstances. Consequently changes in attitudes do not always result in changes in behavior. (*O'Connell 1974*)

2. Behavior representative of feeling or conviction. A disposition that is primarily grounded in affect and emotion and is expressive of opinions rather than beliefs. (*Webster 1963*)

Also contrast with **Belief and Opinion.**

Auger mining. See **Mining, auger.**

Autotrophic organism

An organism capable of synthesizing organic matter from inorganic substances. (*Geckler, et al. 1963*)

In contrast, a **heterotrophic organism** must have organic matter as its

source of food. (*After Geckler et al. 1963*)

Average daily traffic (ADT)

The average 24-hour volume of traffic, being the total volume of traffic during a stated period divided by the number of days in that period. Unless

otherwise stated, the period is 1 year. (*U.S. Forest Serv., FSM 7720.5, Oct., 1970*)

Avoidable risk. See **Risk, avoidable.**

Azonal soil. See **Soil horizon, definition 2.**

B

Backcountry

1. An imprecise term often used to refer to all those portions of **wildlands** in which usually there are no permanent, improved or maintained access roads or operational, fixed facilities—such as lumber mills, ski resorts, or settlements with permanent residents. Deteriorating, unused and unoccupied structures may be present. Those roads which are present are only usable by trucks or 4 wheeled-drive vehicles and typically dead-end in the “backcountry”, rather than continue through it. Any presently active uses only have primitive facilities—e.g., backwoods cabins, base camps, undeveloped campgrounds.

In common usage, **primitive** and **wilderness** areas are backcountry types of wildlands which show no obvious evidence of permanent human uses or occupancy. (*After A.W.M.*)

2. Any area where the management objectives stress dispersed, off-road recreation activities—e.g. hiking, trail bike riding, hunting, fishing.

“Backcountry” is defined as a recreation area while “wilderness” is defined primarily as a large natural ecosystem, to be experienced as it is. Recreational opportunities can be enhanced or even created in “backcountry”, but not in “wilderness”. (*Lucas and Stankey 1974*)

Background

1. The distant part of a scene, landscape, etc. (*Webster 1963*)

2. Surroundings, especially those

behind something and providing harmony or contrast. (*Webster 1963*)

3. The portions of a view between 3 or 5 miles from the observer and as far into the distance as the eye can detect the presence of objects.

Skylines or ridge lines against other land surfaces are the strongest visual elements of the “background”. (*After Litton 1968*)

Also see **Foreground** and **Middle-ground.**

Background level (Background, Natural background level)

The ever-present environmental conditions or effects above which a phenomenon must manifest itself in order to be detected. (*U.S. Dep. Def. 1968*)

Back lighting

1. A viewing situation in which sunlight is coming toward the observer from behind a feature or elements in a scene. (*After Litton 1966*)

2. The viewing condition whereby an observer looks toward the light source. Solid objects are seen in shadow, silhouette, translucence and/or with highlighted edges. (*After Litton 1966*)

Balanced objectivism

An idealistic point of view which advocates that resource use decisions should be reached in a completely objective manner—not disproportionately influenced by any **special interest group** pressure tactics, nor special consideration for any particular segment

of society (whether privileged or disadvantaged) nor any of the other planning value determinisms—biophysical, social, economic.

Balanced objectivism is conceptually unrealistic because it seeks to ignore the political reality of **pressure groups**, fails to recognize that issues (i.e. value conflicts between resource use audience members) are typically the impetus for any planning effort and that most value system clashes cannot be satisfactorily resolved by rational arguments. (*C.F.S.*)

Balance of nature (Ecologic stability)

The apparent stability of the population density relationships between the many species of organisms that make up a **biotic community** is often spoken of as the “balance of nature”.

The concept of such a balance has been severely criticized. It has been pointed out that the population density of each of the species in a biotic community may fluctuate more or less widely from time to time (e.g., existence of population explosions, die-offs, epidemics, irregular migrations, succession etc.) and that the density of no species remains at a fixed value.

The fluctuations in the numbers of each species, however, usually have fairly definite limits. The usage of the term ‘balance’ includes the recognition that the population densities of every species making up a community fluctuate from season to season and from year to year. (*Dice 1952*)

Also see **Ecologic stability**.

Bank erosion. See **Erosion, bank**.

Basal area

1. Range management usage. The area of ground surface occupied by the stem(s) of a range plant, as contrasted with the full spread of its herbage or foliage, generally measured at one inch above soil level. (*Ford-Robertson 1971*)

2. The area of the cross-section of a tree stem near its base, generally at breast height and inclusive of bark. (*Ford-Robertson 1971*)

Also see **Diameter at breast height**.

Base flow

That portion of the water flowing in a stream which is due to ground water seepage into the channel. (*After Soil Conserv. Soc. Amer. 1970*)

Base map

A map showing certain fundamental information, on which is compiled additional data of specialized nature. (*C.F.S.*)

Base property. For range management usage see **Commensurate property**.

Basic assumption. See **Assumption**, definition 2.

Basic productivity. See **Productivity**, primary.

Beach erosion. See **Erosion, beach**.

Bedload

The **sediment** in a stream channel that mainly moves by jumping, sliding or rolling on or very near the bottom of the stream. (*Amer. Geol. Inst. 1962*)

Bedrock

1. The more or less solid rock in place either on or beneath the surface of the earth. It may be soft or hard and have a smooth or irregular surface. (*Soil Conserv. Soc. Amer. 1970*)

2. Any in place, solid rock exposed at the surface of the earth or overlain by unconsolidated material. (*Amer. Geol. Inst. 1962*)

Belief

An unmeasurable and unprovable assertion based on one or more fundamental assumptions. (*O'Connell 1974*)

Also contrast with **Attitude** and **Opinion**.

Benchmark

1. G.A. Hills land evaluation ter-

minology. Certain existing examples or conditions in the field which are usable as established standards or definitions suitable for practical comparison of his "use capability" classes. This is the concept by which units of equal "use capability", but possessing markedly different physical features or appearances, can be recognized as being equal. (*Belknap and Furtado 1967*)

2. The use of assessed "land capability" to serve as a basis from which to estimate the effects on the land of alternative patterns of management. (*U.S. Forest Serv., FSM 2813, Oct., 1973*)

enefit

1. An assessment of the value of the expected outputs. (*U.S. Forest Serv. 1972B*)

2. Desirable effects of a plan or action. (*P.M.R.*)

Also see **Social benefits**.

enefit-cost analysis (Cost-benefit analysis)

An analytical approach to solving problems of choice which identifies for each objective, that alternative which yields the greatest **benefit** for a given **cost** or that alternative which produces the required level of benefits at the lowest cost.

This same analytical process has also been referred to as **cost effectiveness analysis** when the benefits of the alternatives cannot be quantified in terms of dollars. (*U.S. Gen. Account. Off. 1969*)

Also see **Cost-effectiveness analysis** and **Revenue-cost analysis**.

enefit-cost ratio (Cost-benefit ratio)

1. An economic indicator of efficiency, computed by dividing **benefits** by **costs**. Usually, both the benefits and the costs are **discounted** so that the ratio reflects efficiency in terms of the present value of future benefits and costs. (*U.S. Gen. Account. Off. 1969*)

Benthos

The whole group of bottom-dwelling organisms in a water body. The benthos includes all organisms which crawl about on the bottom, or burrow into the bottom or grow attached to the bottom.

Those aquatic organisms that are carried passively by water currents or the wind are termed **plankton** and those that swim actively and may move long distances for feeding or breeding purposes **nekton**. (*Southward 1965*)

Bequest motive. See **Existence value**.

Biochemical oxygen demand. See **Biological oxygen demand**.

Biodegradables

Chemicals or substances which can be readily utilized as part of the biological **food chain** and so broken into their component parts. (*E.C.T.*)

Biogeochemical

1. Relating to the relationship of the earth's chemicals to plant and animal life.

Relating to the chemical relationships between the geology of an area and its plant and animal life. (*After Webster 1963*)

2. As used in **land use planning**, the term is more often used to refer, with one word, to all of the naturally occurring objects, processes and interrelationships in an area than in specific reference to **biogeochemical cycles**.

Often used in the sense of the "biogeochemical parameters" of a planning area or its "biogeochemical environment." In such usages the term "biogeochemical" is approximately equivalent to the natural ecosystem and ecosystem functions of a planning area.

This composite term is based on the assumption that all naturally occurring things can be classified as being either biological, geological or chemical. (*C.F.S.*)

Biogeochemical cycle (Mineral cycle, Nutrient cycle, Material cycle)

1. The circulation (cycling) of chemical elements such as nitrogen, carbon, etc. in specific pathways from the abiotic portions of the environment into the organic substances in the flora and fauna and then back again into abiotic forms. (*After Hanson 1962*)

2. All of the mineral and nutrient cycles involving man, animals, and plants—such as the carbon cycle, phosphorus cycle, nitrogen cycle, etc. (*After Durrenberger 1973*)

Bio(geo)c(o)enose. The translated Germanic and Slavic language equivalent of Ecosystem.

Bio(geo)c(o)enosis. The translated Germanic and Slavic language equivalent of Ecosystem.

Biogeophysical

A composite term often used to encompass, in one word, reference to all of the naturally occurring materials, processes, and relationships operating in an area.

Often used in the sense of the “biogeophysical parameters” of a planning area, or its “biogeophysical environment.” In such usages the term “biogeophysical” is approximately equivalent to the natural ecosystem and ecosystem functions of a planning area.

The word was constructed on the assumption that all the natural objects and processes operating in an area can be classified as being either biological (i.e., plant and animal species, ecological interactions, biotic productivity, etc.) or geological (i.e., rock types, soil types, geomorphic history, sedimentation, erosion, etc.), or physical (i.e., heat, light, electrical, gravitational, etc.) (*C.F.S.*)

Biological management unit

U.S. Forest Service usage. This term includes a big-game management unit

as recognized by cooperating states even though it may not be strictly a herd unit. It may include a drainage system in the case of fishery management, any unit for species management, or any unit of intensive or special management. (*U.S. Forest Serv., FSM 2624.3, Sept., 1970*)

Biological oxygen demand (BOD, Biochemical oxygen demand)

A measure of the demand on a water body's dissolved oxygen supply which will be generated (over some specified period of time) by the biological decomposition of various additions of organic wastes.

A high BOD may temporarily, or permanently, so deplete oxygen in water as to kill aquatic life. The determination of BOD is perhaps most useful in evaluating impact of wastewater on the receiving water bodies. (*After Feth 1973*)

Also see Chemical oxygen demand.

Biological potential. See Biotic potential.

Biological primacy. See Biophysical determinism.

Biologic diversity (Species diversity, Biotic diversity)

In common usage “biologic diversity” is usually equivalent to species diversity—i.e., the number of different species occurring in some location or under some condition such as pollution.

“Biologic diversity” may also be used in a more general sense to refer to the number of higher taxonomic levels or types and amounts of organismal relationships in some location or under some condition—e.g., number of genera, families, orders or phyla present; or the number of biotic communities present; or the number of energy, nutrient, or food chain pathways present. (*C.F.S.*)

Biologic stability. See Ecologic stability.

Biomass (Protoplasm mass)

1. The total weight of the living organisms in some biological system. (*Odum 1971*)

2. The total quantity (at a given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass), (*Hanson 1962*)

Biome

A major biotic community composed of all the plants and animals and smaller biotic communities, including the successional stages of an area. The smaller communities in a biome possess certain similarities in gross external appearances (e.g., deciduous trees, coniferous trees, grasslands, savanna/woodlands) and environmental conditions present (especially gross climatic conditions—e.g., desert, tropical, temperate, tundra). The North American Grassland is an example of a named biome. (*Hanson 1962*)

While a particular biome is defined in terms of both the plants and animals present in an area, it is usually identified and named in terms of the characteristic vegetation forms. (*Webster 1963*)

Also see **Biome-type**.

Biome-type

A group of similar Biomes—e.g., the temperate deciduous forest biome-type includes all areas dominated by deciduous forests in eastern Asia, China, Manchuria, Europe and North America. (*Hanson 1962*)

Some other examples are the tropical rain forest biome-type, tropical savanna biome-type, northern coniferous forest biome-type, temperate grassland biome-type. (*C.F.S.*)

Also see **Biome**.

Biophysical

1. Of or relating to the physics of living organisms. Involving the applica-

tion of physical principles and methods to biological problems.

Involving biological and physical factors or considerations. (*Webster 1963*)

2. In land use planning the term is used to encompass, in a single word, reference to all the naturally occurring objects and processes of an area.

The word is used in such a sense on the assumption that all naturally occurring things can be classified as being either living (i.e., biotic) or nonliving (physical or abiotic). (*C.F.S.*)

Biophysical determinism

A particular point of view in planning which advocates making resource allocation and use decisions primarily on the basis of the inherent ability of the resource to sustain use—i.e., an **ecologic carrying capacity** concept of resource capability. Economic and social system needs and desires are viewed as being completely subordinated to this inherent capacity of the resource to meet any and all demands while maintaining its natural integrity, condition, and performance of other natural processes at a desirable level. Economic and social demands can only be satisfied within the ecologic carrying capacity constraints.

The terms “biological primacy,” “physiographic determinism,” and “ecological determinism,” in their common usage, are equivalent to biophysical determinism—though “biophysical” more clearly implies concern with both physical and biological processes. (*C.F.S.*)

Biosphere

That part of the earth's crust, waters and surrounding air-layer which is inhabited by living organisms. (*Dansereau 1957*)

Biota

The plants and animals of an area, taken collectively. (*After Webster 1963*)

Biotic

All the natural living organisms in a planning area and their life processes.

The term "biotic" in land use planning contexts is most commonly used as a resource classification category which subdivides the natural resources and properties into either the biota and living characteristics or the abiotic (nonliving) entities and characteristics.

Man and his activities are not usually grouped with either of these categories because he is not considered to be a part of a planning area's natural entities or characteristics. This latter rationale for exclusion becomes tenuous when one encounters situations in which native cultures have been actively influencing the course of biotic activity for centuries. (C.F.S.)

Biotic association. See **Biotic community.**

Biotic carrying capacity. See **Carrying capacity, ecological, definition 4.**

Biotic climax. See **Climax community, definition 3.**

Biotic community (Community, Association, Biotic association, Ecologic community)

1. A "biotic community" is any assemblage of populations living in a prescribed area or physical habitat; it is a loosely organized biotic unit to the extent that it has characteristics additional to its individual species and populations components. Communities have functional unity, characteristic trophic structures and patterns of energy flow. They also have taxonomic unity (in that there is a certain probability that certain species will occur together) and a relatively uniform appearance. Communities may be sharply defined. Very frequently, however, communities blend gradually into one another. (Odum 1959)

2. A general term used to designate biotic sociological units of all degrees from the simplest (as an unrooted mat

of algae) to the most complex ecosystem (as a multistoried rain forest). (Carpenter 1938)

3. The word community may be used for any large or small assemblage of organisms. It can be used in an abstract or a concrete sense. (Daubemire 1968)

4. An aggregate of organisms which forms a distinct ecological unit. Such a unit may be defined in terms of flora, of fauna, or both.

Community units may be very large, like the continent-wide coniferous forest, or very small, like the community of invertebrates and fungi in a decaying log. The extent of a community is limited only by the requirement of a more or less uniform species composition.

A different community occurs in each different habitat and environmental unit of larger size, and in fact the composition and character of the community is an excellent indicator of the type of environment that is present.

Since "plant communities" and "animal communities" occur together in the same habitat and have many interrelations, the one can scarcely be considered independently of the other. Together they make up the "biotic community". (Kendeigh 1961)

Biotic diversity. See **Biologic diversity.**

Biotic potential (Reproductive potential, Biologic potential, Reproductive capacity)

The inherent ability of an organism to multiply in the absence of extrinsic controlling factors.

This potential depends on the number of live, fertile offspring produced at each reproduction, the frequency of reproduction and, where sex is involved, the sex ratio. (Soc. Amer. For. 1958)

Biotic productivity. See **Productivity, biotic.**

Black box

An unknown and often unknowable mechanism or system whose operation is judged solely by observation of its **inputs** and **outputs**. (*U.S. Forest Serv. 1972B*)

BLM

Bureau of Land Management, U.S. Department of Interior.

Blob diagram. See **Diagrammatic representation**.

Block diagram

A drawn illustration of a piece of land (or water) in three dimensions which displays the land's surface appearance bounded around the exposed sides by a cutaway representation of the underground (underwater) conditions at those edges. Commonly the land surface is tilted toward the viewer and image size is not reduced with distance from viewer—as would truly occur in accordance with the rules of **perspective**.

The end result is a pictorial representation which appears as if a block of land (or water) had been cut out of its true surroundings and lifted up so as to reveal both its surface and underground characteristics. (*C.F.S.*)

Bloom (Algal bloom, Water bloom)

1. A readily visible, concentrated growth or aggregation of **plankton** (plant and/or animal). (*Geckler, et al. 1963*)

2. A prolific growth of plankton. A "bloom" of algae may be so dense that it distinctly colors the water. (*Veatch and Humphreys 1966*)

Blow down. See **Windthrow**.

Boardfoot

Lumber or timber measurement term. The amount of wood contained in an unfinished board one inch thick, 12 inches long, and 12 inches wide. (*E.C.T.*)

BOD. See **Biological oxygen demand**.

Botanical area

U.S. Forest Service usage. An area which has been designated by the Forest Service as containing specimens or group exhibits of plants, plant groups, and plant communities which are significant because of form, color, occurrences, **habitat**, location, **life history**, arrangement, **ecology**, environment, rarity, and/or other features. (*U.S. Forest Serv., FSM 2362.43, July, 1973*)

Areas of this type and all other **special interest areas** are identified and formally classified primarily because of their recreational values. Areas with similar types of values of scientific importance are formally classified as "Research Natural Areas" (See **Natural Area, Research**). (*W.W.*)

Boundary species. See **Species, peripheral**.

Browse

1. That part of the current leaf and twig growth of shrubs, woody vines and trees available for animal consumption. (*Amer. Soc. Range Manage. 1964*)

2. Act of consuming browse. (*Amer. Soc. Range Manage. 1964*)

Brush

1. A growth of shrubs or small trees usually of a type undesirable to livestock or timber management. (*Amer. Soc. Range Manage. 1964*)

2. A collective term that refers to **stands** of vegetation dominated by shrubby, woody plants or low growing trees—regardless of whether some of the components are cropped. (*After Sampson and Jespersen 1963*)

Brush control

Reduction of **brush** to: (1) reduce its competition for space, moisture, light and nutrients with plant species that are more preferred by grazing animals, or, (2) to reduce the **wildfire** hazard by reducing the amount of fuel present. (*After Amer. Soc. Range Manage. 1964 and T.E.A.*)

Brush management

Management and manipulation of stands of **brush** by mechanical, chemical, or biological means or by **prescribed burning**. (*After D.E.H. and B.W.*)

Buffer (Buffer strip, Buffer zone, Environmental corridor, Filter strip)

1. A designated land or water area, along the perimeter of some land use, whose own use is regulated so as to resist, absorb or otherwise preclude unwanted **development** or other intrusions into areas beyond the buffer. (*After U.S. Bur. Outdoor Recreation 1974*)

2. A strip of undisturbed vegetation that retards the flow of runoff water, causing deposition of transported material and thereby reducing sedimentation of receiving streams. (*U.S. Environ. Prot. Agency 1974*)

Also see **Environmental corridor**.

Buffer strip. See **Buffer**.

Buffer zone. See **Buffer**.

Bulk density

The mass or weight of oven-dry soil per unit of bulk volume, including air space. (*Hanson 1962*)

Bundle of rights. See **Property rights**.

C

Cable logging. See **Logging, Cable**.

Calefaction. See **Thermal pollution**.

Canopied landscape. See **Landscape, canopied**.

Capability (Inherent capability, Inherent carrying capacity, Natural capability, Natural carrying capacity, Physical carrying capacity, Resource bearing capacity, Site capacity)

1. In land use planning literature the widely used terms "suitability" and "capability" (whether alone or accompanied by various modifiers) are often used interchangeably to refer to ratings based on two basically different evaluation procedures. One basic type of evaluation procedure is the rating of use or productivity potentials based on the present state of the resource. This type of rating therefore is an evaluation based on the resource's inherent, natural or intrinsic ability to provide for use and includes that existing ability which is the result of past alterations or current management practices. A second basic type of evaluation procedure rates the potential ability of a resource to produce goods or services on the basis of the maximum possible outputs for a given type and level of future,

alternative site or resource management inputs.

G. Angus Hills was probably the first prominent wildland planner to recognize the importance of retaining the distinction between these and other types of evaluations in a process for land use planning. Hills used the terms **use capability** to refer to evaluations based on a resource's inherent or present condition abilities, **use suitability** for evaluations based on potential management inputs, and **use feasibility** to refer to usability potential ratings based on an evaluation of offsite factors—such as **accessibility** present and **forecasted** socioeconomic conditions, technological developments, etc. (*Belknap and Furtado 1967; Hills, Love and Lacate 1970*)

Perhaps even earlier than Hills, the U.S. Soil Conservation Service began widespread use of its **land capability classification** system (*Wohletz and Dolder 1952*) which also uses "capability" evaluation in the sense of an inherent ability rating.

To avoid confusion in the future we recommend that the Hills and Soil Conservation Service usages be recognized as having established the precedent for

the proper usage of these terms, thus "capability" should be used when referring to evaluations for usability based on the present state of the resource and "suitability" should only be used for evaluations based on assumptions about potential usability or productivity if specified management alterations were to be made—such as drainage improvements, added irrigation and/or fertilization, etc.

Better yet, both terms should be accompanied by modifiers which make it absolutely clear just what type of an evaluation procedure is implied by the rating given. Thus the word capability should always be presented as "inherent capability", "intrinsic capability", or "natural capability". Similarly "suitability" could be referred to as "managed suitability". (*C.F.S.*)

2. The intrinsic ability (i.e., ability unaltered by any level of potential, future human management activities or other type of alternation) to support a given use type, intensity, and quality on a sustained basis (i.e., without significant resource deterioration over the time span of renewing **biogeochemical cycles**). (*C.F.S.*)

Capability, inherent. See **Capability**.

Capability, intrinsic. See **Capability**.

Capability, natural. See **Capability**.

Capacity, highway

The maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway in one direction (or in both directions for a two-lane or a three-lane highway) during a given period of time under prevailing roadway and traffic conditions. In expressing capacity it is essential to state the "prevailing roadway and traffic conditions" under which the capacity is applicable. (*Highw. Res. Board 1965*)

Capital

One of the major factors of produc-

tion consisting of property from which an income is derived, expressed in terms of money. Popularly, the term is frequently used interchangeably with **capital good**. (*Sloan 1961*)

Capital good

A material economic good other than **land** which is used for the production of wealth. Capital goods are created by man. Capital goods are sometimes called "intermediate goods" because of their function of serving consumers only indirectly in satisfaction of their wants. (*After Sloan 1961*)

Carbon cycle

1. The sequence of transformation undergone by carbon utilized by organisms wherein it is used by one organism, later liberated upon the death and decomposition of the organism, and returned to its original state to be reused by another organism. (*Soil Conserv. Soc. Amer. 1970*)

2. The name given to the **biogeochemical cycle** involving the carbon dioxide of the atmosphere in the metabolism of organisms. The cycle begins with: (1) the photosynthesis of carbohydrates by plant chlorophyll from atmospheric carbon dioxide and water. (2) These carbohydrates are then transformed by plants and animals into the structures and energy for their growth and life processes. (3) The carbon dioxide is returned to the atmosphere by the excreta and decay of their bodies. This third step is aided by the action of bacteria and other microorganisms and by combustion. The carbon cycle operates concurrently with the **nitrogen cycle** and the **oxygen cycle**. (*Marsh 1964*)

Cardinal value (Cardinal unit)

The numerical values assigned to a variable which relate directly with some physical property (height, weight, etc.). Each number has some meaning by itself about the measured property. (*E.C.T.*) Also see **Ordinal values**.

Carnivore

An organism (plant or animal) that feeds on animal substances. (*After Hanson 1962*)

Also see **Herbivore**, **Omnivore**, and **Detrivore** for the other types in this classification of organisms by their dominant eating styles.

Carrying capacity (Holding capacity)

All definitions of the concept "carrying capacity" (as it relates to wildland planning) must involve specification of some (1) level of use (2) which will allow for the perpetual maintenance (3) of some level of **environmental quality** (4) within some management objective level set with respect to the cost of maintenance resource quality (5) at a level which will provide resource user satisfaction. (*After G.P.*)

Carrying capacity, aesthetic recreational.

See **Carrying capacity, wildland, recreation**, definition 5.

Carrying capacity, Ecological (Inherent capability, Inherent carrying capacity, Natural capability, Natural carrying capacity, Physical carrying capacity, Resource bearing capacity, Site capacity, Biotic carrying capacity)

1. The number (or weight) of organisms of a given species and quality that can survive in, without causing deterioration of, a given ecosystem through the least favorable environmental conditions that occur within a stated interval of time. (*Ford-Robertson 1971*)

2. The limit of a natural ecosystem's ability to sustain user impacts. (*After Conservation Foundation 1972*)

3. Strictly speaking, any level of use greater than zero will always result in some alteration of natural environments, and therefore, it is not useful to define ecological carrying capacity in "no change" terms. Some decision about what is an acceptable amount of alteration of natural values must first

be made before ecological carrying capacity can be operational for setting levels of use. (*C.F.S.*)

4. "Biotic carrying capacity" used in a recreational context. That level of development and use beyond which the site's capacity to provide a sustained high level of satisfaction becomes impaired due to severe damage. (*La Page 1963*)

5. "Physical carrying capacity". The effect of use on the nonliving aspects of the habitat—e.g., the ability of a particular **terrain** to resist trail erosion, but also the ability of the terrain to absorb trails, roads, and other man-made objects. (*Conserv. Found. 1972*)

Carrying capacity, economic recreation (Visitor carrying capacity)

The **econometrically** determined number of people which maximizes total **social benefit**; the number of recreationists represented by the high point on a cumulative benefit curve—with some measure of "enjoyment" on the vertical axis and the number of recreationists on the horizontal axis. At this high point on the curve, no further overall "enjoyment" is gained by adding other recreationists. Rather, adding still more results in a net decline in the totaled "enjoyment" of all recreationists. (*After Alldredge 1972*)

Carrying capacity, facility

1. The number of people which installed facilities have been engineered to handle. (*After Alldredge 1972*)

2. The maximum capacity of the developments and facilities—e.g. number of rooms, etc. (*After Sudia and Simpson 1972*)

3. The number of users which facilities are able to (or designed to) support, within some acceptable rate for facilities deterioration (in relation to amount or intensity of use) and at some level of facilities maintenance—while providing a desirable level of service for users. (*C.F.S.*)

Carrying capacity, natural. See **Carrying capacity, ecological.**

Carrying capacity, optimal. See **Carrying capacity, wildland, recreation, definition 4.**

Carrying capacity, physical. See **Carrying capacity, ecological.**

Carrying capacity, psychological

The level of use beyond which the sensory and conceptual quality of the resource begins to deteriorate for some particular user group because of an unacceptable amount of contact with other similar users or proximity to types of use incompatible with their mental image of an acceptable quality resource environment.

The notion of psychological carrying capacity essentially revolves about the conceptual level of utilization at which resource users (especially wildland recreationists) begin to feel that the number of simultaneous users has become so great that the resource is too crowded to satisfy their demands. (*C.F.S.*)

Carrying capacity, range

In its true sense, the maximum number of individual animals that can survive the greatest period of stress each year on a given land area. It does not refer to sustained yield.

In range management, the term has become erroneously synonymous with **grazing capacity**. (*Amer. Soc. Range Manage. 1964*)

Carrying capacity, social. See **Carrying capacity, psychological.**

Carrying capacity, visitor. See **Carrying capacity, economic recreation.**

Carrying capacity, wildland recreation

1. The level of recreational use an area can withstand while providing a sustained quality of recreation. (*After Wagar 1964*)

2. The character of use that can be supported by an area over a specified

time interval and which is developed at a certain level without causing excessive damage to the physical environment or the experience for the visitor. (*After Lime and Stankey 1971*)

3. The number of persons for which an area can provide recreation while maintaining the conditions that originally made it desirable for that purpose. (*After Sudia and Simpson 1972*)

4. The level of use at which the natural resources do not deteriorate faster than they can be restored by a reasonable level of maintenance ("optimal carrying capacity" definition). (*After Sudia and Simpson 1972*)

5. La Page's "aesthetic recreational carrying capacity". La Page considered "recreational carrying capacity" to have an "aesthetic recreational carrying capacity" and a "biotic carrying capacity" component.

His "aesthetic recreational carrying capacity" is that level of development and use beyond which measurable decreases in average satisfaction occur as a direct result of gross numbers of recreationists. (*La Page 1963*)

For La Page's "biotic carrying capacity" see **carrying capacity, ecological, definition 4.**

6. The substitution of the terms "use limits" or "use-intensity-quality relationships" in place of "recreation carrying capacity" and "social carrying capacity" when it is being used in the latter sense has been advocated. The argument is that rather than having a single capacity, which is seen to be implied by using the term "carrying capacity," each site has a whole range of potential capacities, each providing different consequences. Therefore, even if it can be shown how areas and experiences will change with various levels of use and various management practices, someone must still decide what changes are acceptable. Defining what is acceptable is a value choice rather than a technical issue. (*After Wagar 1974*)

Carrying capacity, wildlife

1. The number of animals of a given species that a **habitat** supports, measured at the low stage of any annual population cycle. (*After Allen 1958*)

2. The upper limit of population growth beyond which no major increase can occur. (*After Odum 1959*)

3. The number of animals that a habitat can maintain in a healthy, vigorous condition. (*After Dasmann 1945*)

4. The level at which a population is normally held by hunting and predation. (*After Errington 1945*)

5. The level of population above which intraspecific tolerance permits no further increase. (*After Leopold 1933*)

Catchment area. See **Watershed**.

Catchment basin. See **Watershed**.

Census tract

U.S. Bureau of the Census usage. Census tracts are small areas into which large cities and adjacent areas have been divided for statistical purposes. In each **standard metropolitan statistical area**, tracts were established by the Bureau of the Census in cooperation with a local committee. Tracts were generally designed to be relatively uniform with respect to population characteristics, economic status, and living conditions. The average tract has about 4,000 residents. Tract boundaries are established with the intention of being maintained over a long time so that comparisons may be made from census to census. (*U.S. Bur. of the Census 1971*)

Central city. See **Urbanized area**.

CEQ

Council on Environmental Quality, U.S. Presidential.

Channel storage

The volume of water which is temporarily present (stored) in a stream channel and its **flood plain** while enroute to an outlet. (*After Soil Conserv. Soc. Amer. 1970*)

Characteristic landscape. For U.S. Forest Service usage see **Visual landscape character**.

Character subtype. For U.S. Forest Service usage see **Visual character subtype**.

Character type. For U.S. Forest Service usage see **Visual character type**.

Chemical oxygen demand (COD)

A measure of the amount of a water body's **dissolved oxygen** supply that would be used up in completely oxidizing added inorganic oxidizable compounds—such as in the oxidation of ammonia to nitrate. (*After Feth 1973 and Wash. State Univ., Coop. Ext. Serv. 1972*)

Biological oxygen demand (BOD)

Tests can only measure the biodegradable fraction of the total potential dissolved oxygen consumption by added wastes; however, COD tests may be used to measure the oxygen demand created by toxic organic or inorganic compounds as well as by biodegradable substances. A standard COD test, therefore, can be used to evaluate many industrial type wastes not readily analyzed for water quality factors by the sewage-oriented BOD test. (*After Mc Gauhey 1968*)

Also see **Biological oxygen demand**.

Choropleth map

A map showing discrete areas, such as counties, soil units, vegetation types. These units are considered to be uniform with respect to the statistics collected within them. (*Amidon 1972*)

City planning (Urban planning)

The process of guiding growth and change in urban areas.

“City planning” aims at fulfilling certain social and economic objectives which go beyond the physical form and arrangement of the parts of the physical urban environment. (*Howard 1961*)

Claim. See **Mining claim**.

Classification

1. The forming, sorting, apportioning, grouping, or dividing of objects into classes to form an ordered arrangement of items having a defined range of characteristics. Classification systems may be taxonomic, mathematical, or other types, depending upon the purpose to be served. (*U.S. Forest Serv. 1972B*)

2. The ordering or arrangement of objects into groups or sets on the basis of their relationships. These relationships can be based on observable or inferred properties.

The paramount purpose of classification is to describe the structure and relationships of the constituent objects to each other and to similar objects, and to simplify these relationships in such a way that general statements can be made about classes of objects.

"Natural classification" schemes attempt to reflect the natural processes that have led to the observed arrangement of objects. From such an ordering it is hoped to learn about the laws governing the behavior of these objects.

All classifications aim to achieve economy of memory and an ease of manipulation. (*After Sokal 1974*)

Also see **Taxonomy**.

Class, social. See **Social class**.

Clay

1. "Particle size" usage. Rock type particles which are less than 0.002 (or 0.005 or 0.074) millimeters in equivalent diameter. (*Soil Conserv. Soc. Amer. 1970 and Amer. Geol. Inst. 1962*)

2. "Clay Mineral." Naturally occurring inorganic, crystalline minerals composed of fragments of hydrous aluminum silicate minerals found in soil and other earthy deposits. (*Soil Conserv. Soc. Amer. 1970*)

3. "Soil texture" usage. A soil texture type consisting of 40 percent or more clay-sized particles, less than 40 percent silt-sized particles and less

than 45 percent sand-sized particles. (*Soil Conserv. Soc. Amer. 1970*)

4. Material behavior usage. A natural, inorganic material with plastic properties. (*Amer. Geol. Inst. 1962*)

5. Engineering usage. A fine-grained soil that has a high plasticity index in relation to the amount of water it can hold without losing its plasticity. (*Soil Conserv. Soc. Amer. 1962*)

Cleaning cut

Timber management usage. Cleaning is applied to stands not past the sapling stage. Usually, if otherwise practical, this is best done as soon as the stand has passed browse height, but not until the removal cut has been completed.

At this stage, genetic differences are likely to be easily recognized; opportunity to improve species composition is at a maximum; and not much production loss to unusable stems will have to be accumulated—with the possible exception of areas where rainfall exceeds vegetative needs. (*U.S. Forest Serv., FSM 2471, June, 1973*)

Clearcutting

1. Removal of virtually all the trees, large or small, in a stand in one cutting operation.

This is the meaning of "clearcutting" in its narrowest sense and in its usage as a technical term of silviculture. The true clearcutting method lays bare the area treated and leads to the establishment of an even-aged stand. (*Smith 1962*)

2. The term "clearcutting" is also loosely applied to any type of cutting in which all the merchantable timber is cut and all trees that cannot be utilized profitably are left.

This broader usage of the term is technically incorrect but is so common that it is sometimes prudent to speak of clearcutting in the silvicultural method sense as "complete clearcutting". (*Smith 1962*)

Also see **Cutting** and **Logging**, defi-

nition 2, for the distinction between **Silviculture** and **Harvesting**.

Clearcutting system

A **silvicultural** system in which all the trees are cleared over a considerable area at one time. **Regeneration** is generally artificial, but natural regeneration is sometimes possible by seeding from the air, from adjacent stands, or from seed and/or advance growth already on the ground. (*Ford-Robertson 1971*).

Also see **Silviculture** or **Logging** for the distinction between these terms and **Harvesting** and **Cutting**.

Climate

The average course or condition of the **weather** at a particular place over a period of many years as exhibited in absolute extremes, means, ranges and seasonal distribution of air temperature, wind velocity and direction, precipitation type, duration and amount, humidity and other weather elements. (*After Webster 1963*)

Also contrast with **Weather**.

Climax community (Climax)

1. The final or stable **biotic community** in a developmental series (**sere**); it is self-perpetuating and in equilibrium with the physical **habitat**. (*Odum 1971*)

2. The **plant community** which, in a given area, perpetuates itself indefinitely on the best-drained land form and the most differentiated (well-developed) soil. (*Dansereau 1957*)

3. The kind of biotic community capable of self perpetuation under the prevailing climatic and soil conditions; the terminal stage of a **sere** under the prevailing conditions.

A "physiographic climax" is a "climax" determined in large measure by the nature of the topography or soil—e.g., a particular type of forest may be the "climax" on a north-facing slope while a grassland may be the "climax" on the south-facing slope of the same

ridge.

An "edaphic climax" is a "climax" determined largely by the nature of the soil conditions—e.g., a saltgrass marsh in a poorly drained, alkaline depression in grassland.

A "biotic climax" is a "climax" caused by a permanent influence or combination of influences caused by one or more kinds of organisms, including man. (*Hanson 1962*)

4. That point in the development of a community when the changes that normally occur in ecological succession cease. The main biotic components are not overthrown by new invaders. No new species become dominant in the biotic community. The environmental conditions of the habitat are relatively stabilized. (*After Woodbury 1954*)

Also see **Succession**.

Climax species

The members (or a member of) those plant and animal species present in a **climax community**.

Frequently used in the sense of species usually present (or at least common) only as members of a climax community. (*C.F.S.*)

Climax vegetation

1. The group of plant species which is the culminating stage in plant succession for a given set of environmental conditions. (*C.F.S.*)

2. A relatively stable type of vegetation in equilibrium with its environment and with good selfperpetuating reproduction of the dominant plant species. (*After Soil Conserv. Soc. Amer. 1970*)

3. The aggregate pattern or complex of **climax plant communities** (which corresponds to the pattern of changing environmental factors and their values) over an area. (*After Hanson 1962*)

Also see **Climax species**.

Closed area

Range management usage. Any area

closed for management purposes for certain types of use. (*Amer. Soc. Range Manage.* 1964)

Closed range. See **Range, closed.**

Cluster development (Planned unit development, PUD)

1. The grouping of the structures in a housing development more tightly together and using the open land thus saved for common greens and squares. (*Whyte 1964*)

2. Residential development in which the subdivision and zoning regulations apply to the project as a whole rather than to its individual lots (as in most tract housing). Densities are calculated on a project-wide basis, permitting among other things the clustering of houses and provision of common open space.

Potential advantages include: an improved site design free of standard lot pattern limitations; lower street and utility costs made possible by reduced frontages; more useful open space due to reduction or elimination of the unusable side and front yards required by traditional zoning; greater flexibility in the mixing of residential building types; the possibility through its greater freedom in design of increasing over-all densities without loss of essential amenities. (*Abrams 1971*)

Cluster zoning. See **Zoning, cluster.**

Coastal state

Coastal Zone Management Act usage. A state of the United States in, or bordering on, the Atlantic, Pacific, or Arctic Ocean, the Gulf of Mexico, Long Island Sound, or one or more of the Great Lakes. For the purposes of this title, the term also includes Puerto Rico, the Virgin Islands, Guam, and American Samoa. (*Coastal Zone Manage. Act 1972*)

Coastal waters

Coastal Zone Management Act usage. "Coastal waters" means (1) in

the Great Lakes area, the waters within the territorial jurisdiction of the United States consisting of the Great Lakes, their connecting waters, harbors, roadsteads, and estuary-type areas such as bays, shallows, and marshes and (2) in other areas, those waters, adjacent to the shorelines, which contain a measurable quantity or percentage of sea water, including, but not limited to, sounds, bays, lagoons, bayous, ponds, and estuaries. (*Coastal Zone Manage. Act 1972*)

Coastal zone

Coastal Zone Management Act usage. The coastal waters (including the lands therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each other and in proximity to the shorelines of the several coastal states, including transitional and intertidal areas, salt marshes, wetlands, and beaches. The zone extends, in Great Lakes waters, to the international boundary between the United States and Canada and, in other areas, seaward to the outer limit of the United States territorial sea. The zone extends inland from the shorelines only to the extent necessary to control shorelands, the uses of which have a direct and significant impact on the coastal waters. Excluded from the coastal zone are lands the use of which is by law subject solely to the discretion of or which is held in trust by the Federal government, its officers or agents. (*Coastal Zone Manage. Act 1972*)

Coastal Zone Management Act of 1972 (P.L. 92-583) 86 Stat. 1280

Finds and declares that it is the national policy (A) to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations, (B) to encourage and assist the states to exercise effectively their responsibilities in the

coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone giving full consideration to ecological, cultural, historic, and esthetic values as well as to needs for economic development, (C) for all Federal agencies engaged in programs affecting the coastal zone to cooperate and participate with state and local governments and regional agencies in effectuating the purposes of this title, and (D) to encourage the participation of the public, of Federal, state, and local governments and of regional agencies in the development of coastal zone management programs. With respect to implementation of such management programs, it is the national policy to encourage cooperation among the various state and regional agencies including establishment of interstate and regional agreements, cooperative procedures, and joint action particularly regarding environmental problems.

Authorizes the Secretary of Commerce to make annual grants to any coastal state for the purpose of assisting in the development of a management program for the land and water resources of its coastal zone. (*Coastal Zone Manage. Act 1972*)

COD. See **Chemical oxygen demand.**

Cold-water fishery

Stream and lake waters which support predominantly cold-water species of game or food fishes, which have maximum, sustained water temperature tolerances of about 70 degrees Fahrenheit in the summer. Salmon, trout, grayling, and northern pike are examples. (*U.S. Forest Serv., FSM 2605, Sept., 1974*)

Colluvium

Mixed deposits of soil material and rock fragments accumulated near the base of steep slopes through soil creep, landslides, and local surface runoff.

(*Durrenberger 1973*)

Commensurability

Range management usage. Capacity of a permittee's base ranch property to support permitted livestock during the period such livestock are off public land. (*Amer. Soc. Range Manage. 1964*)

Commensurable values

1. Having a common unit of measure. (*Webster 1963*)

2. The state of being proportionate. (*Webster 1963*)

3. Resource yields which can be objectively compared because their values can be expressed quantitatively on the same measurement scale (such as in dollars, pounds, or cubic feet). (*C.F.S.*)

Commensurate property (Base property)

Range management usage. Land or controlled livestock water which qualifies a person for a **grazing preference** on other land, either public or private. (*Amer. Soc. Range Manage. 1964*)

Commercial/industrial land

Land used primarily for buying, selling, and processing goods and services and including sites for stores, factories, shopping centers, and industrial parks, together with necessary adjacent facilities such as underground and surface utilities, access streets and alleys, and other servicing structures, appurtenances, and measures. (*U.S. Soil Conserv. Serv. 1970*)

Commodity

A transportable resource product with commercial value; all resource products which are articles of commerce. (*C.F.S.*)

Common law. See **Law, common.**

Common variety mineral. See **Mineral, common variety.**

Community. See **Biotic community** or **Human community.**

Community biomass. See **Biomass, definition 2.**

Community development

Deliberate efforts to foster socio-cultural change on the community level, change of a kind seen as valuable or progressive.

Generally, the goals of development include an improved **quality of life** through increases in resources, skills, facilities, technology, social competence, and **social power**. (*O'Connell 1974*)

Community services land

Land used primarily for schools, hospitals, churches, libraries, sewerage and water treatment plants, sanitary land fills, public parking areas, and other community service facilities, together with necessary adjacent facilities such as underground and surface utilities, access streets and alleys, and other servicing structures, appurtenances and measures. (*U.S. Soil Conserv. Serv. 1970*)

Compartment. See **Timber management compartment**.

Compatible uses

Land uses which can exist together, so that no one use improves nor detracts from the quality of another. In practice this definition is usually relaxed to include uses which can co-exist and conflict only slightly. (*E.C.T.*)

Also see **Incompatible uses**, **Conflicting uses** and **Complementary uses**.

Compensable regulation

Land use regulations which, while restricting the uses which may be made of land, compensate the property owner for any decrease in the value of his land caused by the regulations.

The property is first valued as in a **condemnation** proceeding. Once a fair value is ascertained and agreed upon, the state guarantees the owner that value for his land. The owner then agrees to place the land under regulations controlling its use.

This is a means of strengthening **zoning** by providing compensation for controlled land. (*U.S. Bur. Outdoor Recreation 1974*)

Competition (Ecologic competition)

1. The general struggle for existence (and dominance) in which living organisms compete for a limited supply of the necessities of life. (*Carpenter 1938, citing Yapp 1925*)

2. The condition of rivalry between organisms that exists when a number of organisms (of the same or of different species) utilize common resources that are in short supply; or, if the resources are not in short supply, the condition that occurs when the organisms seeking that resource nevertheless harm one or other in the process. (*Birch 1957*)

Competition typically results in ultimate elimination of the less effective organism from that particular **ecological niche**. (*Webster 1963*)

Competition may be interspecific (i.e., between two or more different species) or intraspecific (i.e., between numbers of the same species). (*Krebs 1972*)

Competition is usually confined to closely related species which eat the same types of food and live in the same sorts of places. (*Krebs 1972*)

Complement

To mutually supply each other's lack. (A design for a site complex which indicates the specific locations of buildings, parking lots, etc. complements the management plans which do not contain this information). (*After U.S. Forest Serv. 1971*)

The distinction between complements and supplements of plans is that complements and the larger plan to which they relate can be viewed as being mutual supplemental because each supplies something which the other lacks; however, plan supplements do not gain anything themselves

by their addition to a plan. (*C.F.S.*)

Also see **Supplement**.

Complementary uses

Land uses, each of which is improved in quality or quantity by the other uses existing with it in the same area. (*E.C.T.*)

Also see **Incompatible uses**, **Conflicting uses** and **Compatible uses**.

Complete clearcutting. See **Clearcutting**, definition 2.

Completeness test

U.S. Water Resources Council (WRC) usage. One of the tests to be applied in choosing among alternatives in planning for water and related land resources while following the WRC principles and standards.

The "completeness test" requires that an alternative plan provide and account for all necessary investments or other actions that will be needed to assure the full realization of the contributions provided by the plan to the components of the objectives specified for the planning area. (*U.S. Dept. of Agri. 1974*)

Complete protection

Range management usage. The withdrawal of all grazing animals from a given range. (*Amer. Soc. Range Manage. 1964*)

Comprehensive development plan. See **Comprehensive plan**.

Comprehensive plan (**Comprehensive development plan**, **General plan**, **Master plan**)

1. City planning usage. An official document adopted by a local government setting forth its general policies regarding the long-term physical development of a city or other area. The plan should be broad enough to include all aspects of a development or redevelopment program as distinguished from sporadic, isolated, or piecemeal planning. It is used inter-

changeably with the terms "general plan" and "city plan" and is probably most familiarly or notoriously known as a "master plan". (*Abrams 1971*)

2. Comprehensive planning—the process of designing futures not only of three dimensional accomplishments in space but also social mechanisms such as laws, regulations, policies and forms of organization. (*Branch 1967*)

When used in this sense, comprehensive planning is conceptually similar to **extraordinary planning**.

3. U.S. Bureau of Land Management usage. "Comprehensive Plan" is intended to include the following: (1) a land plan map which would show the location of all Bureau land, the interrelationship between all of the uses proposed on said land, the circulation system required to serve the uses existing or proposed, and the relationship between the Bureau land and non-Bureau land within a reasonable area of influence. (2) Land use policies related to the resources management, conservation and disposal of public lands. (3) Land use policies related to the activities and the regulations thereof as they affect portions of the Bureau land. (4) Implementation schedules which establish priorities for Bureau programs in management, mapping, engineering and public works. (5) A program for the coordination of land use and activity programs with Federal, state, regional, county and other local agencies as well as with private applicants. (*Eisner 1969*)

4. "Comprehensive planning" includes the following, to the extent directly related to area needs or needs of a unit of **general purpose local government**: (A) preparation, as a guide for governmental policies and action, of general plans with respect to (1) the pattern and intensity of land use, (2) the provision of public facilities (including transportation facilities) and other government services, and (3) the

effective development and utilization of human and natural resources; (B) long range physical and fiscal plans for such action; (C) programming of capital improvements and other major expenditures, based on a determination of relative urgency, together with definitive financing plans for such expenditures in the earlier years of the program; (D) coordination of all related plans and activities of the state and local governments and agencies concerned; (E) preparation of regulatory and administrative measures in support of the foregoing. (*Intergovernmental Cooperation Act of 1963, PL 90-577, Sec. 109*)

5. A plan for the development of an area including policies, goals, and interrelated plans for private and public land use, transportation systems, community facilities, and all other elements and features that, in composite, represent the decisions of local people. (*Soil Conserv. Soc. Amer. 1970*)

6. Also see **Master plan** and contrast with **Incrementalism**.

Computer graphics

Visual displays of information produced by an electronic computer. This includes both 'hard copy' (paper, film) and cathode-ray tube (CRT) displays. Among the common computer graphics are maps, graphs, still drawings, and motion pictures. (*E.C.T.*)

Computer information system

Two or more interacting electronic computer programs designed to facilitate storage, editing, organization, and rapid retrieval and display of large amounts of related information. (*E.C.T.*)

Computer program

1. A complete set of instructions which cause an electronic computer to perform a set task. Several computer programs may operate together to form a computer system. (*E.C.T.*)

2. A plan or routine for solving a

problem on a computer. (*U.S. Forest Serv. 1972B*)

Concentrated recreation. See **Recreation, concentrated**.

Concentration time

The time required for water to flow from the most remote point of a watershed (in a hydraulic sense) to the outlet. (*Soil Conserv. Soc. Amer. 1970*)

Concern

1. Public apprehension about whether some land use action might produce some more or less vaguely defined undesirable results. (*C.F.S.*)

2. A point of dispute which can only be vaguely defined or in which the potential undesirable results of a land use action are more speculative than documentable.

When the relationship between the action and undesirable result can be sharply defined, a point of dispute is referred to as an issue rather than a concern. (*C.F.S.*)

Also see **Crisis**.

Condemnation

In real property law, the process by which property of a private owner is taken for public use, without his consent, but requiring payment of just compensation. (*U.S. Bur. Outdoor Recreation 1974*)

Also see **Condemnation, reverse**.

Condemnation, inverse. See **Condemnation, reverse**.

Condemnation, reverse (Inverse condemnation)

Land use planning regulations may, for the public benefit, sometimes restrain the economic uses which may be made of private property without making any provision for compensating the owner. Such occurrences are sometimes referred to as being reverse condemnation and therefore implicitly constituting a violation of the Fifth

Amendment's prohibition of **taking** property without **just compensation**.

However state land use regulations based on the **police power** authority may substantially diminish the economic value of private property without giving rise to an obligation to compensate the owner. (*After U.S. Dep. Justice comments in U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Also see **Eminent domain** and **Police power**.

Conflicting uses

Land uses by which the quality of each individual use is harmed by the others when they occur together in the same area—due to either competition for limited resources or use byproducts which damage alternative uses. In the extreme when one use prevents another, “conflicting uses” become **incompatible uses**. (*E.C.T.*)

Also see **Incompatible uses**, **Compatible uses** and **Complementary Uses**.

Conservation

1. U.S. Soil Conservation Survey usage. Soil and water conservation means the development, use, and management of soil, water, and related resources in a way that will restore, enhance, protect, and maintain their quality and quantity for the benefit of man and his environment now and into the future. (*U.S. Soil Conserv. Serv. 1970*)

2. Any policy or practice which seeks to increase future usable supplies of a resource by present actions. (*Sesco, et al. 1973*)

3. The use of all methods and procedures which are necessary to bring any **endangered species** or **threatened species** to the point at which measures provided pursuant to this Act (**Endangered Species Act of 1973**) are no longer necessary. Such methods include, but are not limited to, all activities associated with scientific resources management such as research, census,

law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking. (*Endangered Species Act of 1973*)

4. The continuing protection and management of natural **renewable resources**—e.g., soil, water, wildlife, forest—in accordance with principles that assure their optimum economic and social enjoyment. (*Ford-Robertson 1971*)

5. The protection of the renewable resources—e.g., water, forests, fisheries, wildlife, etc.—of man's environment against depletion or waste and the safeguarding of its beauty. (*After Abrams 1972*)

This term has come to mean many different things to many different people. To the naturalist and nature lover it means preserving wild areas in their pristine virginity. To the lumbermen it means harvesting a stand of timber which is no longer producing adequate new annual increments of wood. To the hunter it means increasing or maintaining the abundance of his favorite game. To the hydroelectric engineer, conservation means the building of dams and reservoirs. There are many other meanings. Insofar as these concepts, and similar concepts, mean the elimination of waste they are in a proper sense, conservation. (*Marsh 1964*)

7. Planned management of a **natural resource** to prevent exploitation, destruction, or neglect. (*Webster 1963*)

8. “Conservation” is concerned with the time distribution of use. More specifically conservation is defined in terms of changes in the intertemporal distribution of physical rates of use. In conservation the redistribution of use is in the direction of the future. More use (or emphasis on the availability of

use) of a resource is allocated for times more distant in the future than for use in times closer to the present. Conservation always implies comparison of two or more time distributions of use. For example that concept is used when comparing expected use if new practices are adopted with what use would have been if the old practices had been continued.

Conservation in itself cannot mean non-use. For **nonrenewable** (stock) **resources**, conservation is meaningless when used in the sense of keeping them permanently undiminished and unimpaired. In that sense rates of use would have to remain zero and that portion of the environment could not be considered to be a **resource**.

Interpretations of conservation as being "wise use" or "the greatest use to the greatest number over the greatest length of time" has little precise meaning and is of no value for economic analysis.

"Conservation" is also sometimes defined as keeping use constantly at or less than the rate of regeneration of renewable resources—i.e., the **sustained yield** concept. Such a usage excludes all those cases in which an attempt is made merely to slow down rather than to stop the decreasing rate of regeneration and use. Yet different levels of sustained yield are frequently economic alternatives. Whether any rate of use should be maintained indefinitely may be less relevant economically than what such a rate should be. (*After Ciriacy-Wantrup 1968*)

9. The concept of "conservation" is concerned with the rate, purpose, and efficiency of utilization of natural resources.

Conservation receives impetus from the social conscience awareness of an obligation to future generations. All the varying definitions of the nature of "conservation" as a utilization policy deal with the judicious development

and manner of use of natural resources of all kinds. (*After Lapedes 1974*)

Conservation district. See **Soil Conservation District**.

Conservation easement. See **Easement, conservation**.

Conservation plan

1. U.S. Soil Conservation Service usage. A document containing all major material needed for making decisions that will assure that the soil and water resources of a unit of land (or group of units of land) will be used and treated so as to achieve the conservation objectives which have been set forth.

A "conservation plan" includes but is not limited to "conservation plan maps"; water, plant, animal and other inventory and management information with needed interpretations and evaluations; a record of the decisions made contributing to sound land use and conservation treatment; the alternatives for sound land use(s) and conservation treatment for which conservation decisions have not yet been made (including positive statements about critical problems such as **soil erosion**, sedimentation, land use and agricultural pollutants); records of understandings as to cooperative agreements between individuals, groups or government representatives and resource conservation districts; and other information useful to the decision maker. (*After Soil Conserv. Soc. Amer. 1970*)

2. Usage for farm, ranch, or non-agricultural land units. The properly recorded decisions of the cooperating landowner(s) or operator on how it is planned, within practical limits, to use the land in an operating unit within its **capabilities** and to treat it according to the needs for maintenance or improvement of the soil, water and plant resources. (*Soil Conserv. Soc. Amer. 1970*)

Conservation treatment unit (CTU)

A field or group of fields or other units of land with similar soil and water conservation problems requiring similar combinations of land use and conservation treatment. (*U.S. Soil Conserv. Serv.* 1970)

Conservation zoning. See **Zoning, conservation.**

Constitutional determinism (Judicial determinism, Legal determinism)

A point of view which places emphasis on the legal and judicial environment within which resource use planning decisions must be made. Because resource use planning must operate within such constitutional constraints and provisions as due process, property rights, taking without compensation and protection of public health safety and welfare, the legal aspects of planning are seen as of primary importance in the planning process. All other planning considerations are considered to be subservient to legal considerations. (*C.F.S.*)

Consumer organism (Consumer)

1. An organism which ingests other organisms or food particles. They may be further classified as "primary consumers", "secondary consumers", etc. depending upon their position in the food chain. (*Hanson* 1962)

The "primary consumers" (herbivores) feed directly on plants, and "secondary consumers" (carnivores) feed on the primary consumers. (*Odum* 1953)

2. Organisms, (including some non-green plants but chiefly animals) which ingest and utilize other organisms or particulate organic matter. (*Odum* 1971)

3. For the other two divisions in this particular classification of **biotic community** organisms also see **producer organism** and **decomposer organism**.

Consumer surplus

In economics, the difference be-

tween the price that a consumer pays for a good or a service and the amount that he would be willing to pay rather than be deprived of the good or service. (*U.S. Gen. Account. Off.* 1969)

Also see **Producer surplus** and **Willingness-to-pay**.

Consumptive use

1. Those uses of resources that reduce the supply—such as logging and mining. (*C.F.S.*)

"Consumptive use" as a category does not make any distinction between resources whose supply will sooner or later, build up again after the initial reduction (i.e., **renewable resources**) and resources whose supply will essentially never be renewed (i.e., **nonrenewable resources**). (*C.F.S.*)

For example, for water some "consumptive uses" are irrigation and domestic and industrial use, while **non consumptive uses** would include direct power generation as well as boating, swimming, etc. (*E.M.G.*)

2. The quantity of water used and transpired by vegetation plus that evaporated. (*Soil Conserv. Soc. Amer.* 1970)

Contingency planning. See **Adaptive planning.**

Continuing easement. See **Easement, continuing.**

Continuous grazing. See **Grazing, continuous.**

Continuous use grazing. See **Grazing, continuous.**

Contour (Contour line)

1. An imaginary line on the earth's surface connecting points of the same elevation.

A line drawn on a map connecting points of the same elevation. (*Soil Conserv. Soc. Amer.* 1970)

Contour, approximate original

That surface configuration achieved by backfilling and grading of the mined area so that it closely resembles

that surface configuration of the land prior to mining and blends into and complements the drainage pattern of the surrounding terrain, with all high-walls, spoil banks and depressions eliminated . . . except water impoundments. (*Surface Mining Control and Reclamation Act of 1975*)

Contour interval

The vertical distance between contour lines. (*Soil Conserv. Soc. Amer. 1970*)

Contour line. See **Contour.**

Contour map

A map which portrays the elevational features of an area by joining points of equal elevation with continuous lines, called **contour lines**. (*C.F.S.*)

Contour strip mining. See **Mining, contour surface.**

Controlled burn

1. The planned application of fire to natural fuels, residue left on a site after a logging operation and other slash, with the intent to confine it to a predetermined area. (*After Ford-Robertson 1971*)

2. Any deliberate application of fire to an area where control is exercised in some particular respect. (*Ford-Robertson 1971*)

Also see **Prescribed burn.**

Coordinating criteria

U.S. Forest Service usage. Policy statements of the opportunities and constraints to be applied in carrying out the more intensive planning of planning units. (*U.S. Forest Serv., FSM 8222.2, Oct., 1973*)

Coordinating requirements (Forest coordinating requirements)

U.S. Forest Service usage. Statements of management policy in a national forest land use plan.

Coordinating requirements are policy statements establishing the relationships that are to be maintained be-

tween resources, uses, activities, or ecological systems to meet the objectives set forth in the **planning area guide**. Coordinating requirements state the minimum coordination required in planning and carrying out activities. They consider assumptions about future public demands upon national forest land and forest service management policy. The result is a series of specific statements directing management actions and considerations on a national forest.

Forest "coordinating requirements" supplement management direction contained in the planning area guide.

The forest coordinating requirements may be more specific or restrictive than that stated in the guide, but in no case may they reduce the standards set in the guide. (*U.S. Forest Serv., FSM 8225, Oct. 1973*)

Cord

Cut or pulpwood measurement term. The equivalent of a stack of wood four feet by four feet by eight feet, or 128 cubic feet. (*Webster 1963*)

Cost

The negative (adverse) effects. Costs may be monetary, social, physical, or environmental in nature. (*After U.S. Forest Serv. 1972B*)

Also see **Social costs.**

Cost-benefit analysis. See **Benefit-cost analysis.**

Cost-benefit ratio. See **Benefit-cost ratio.**

Cost effective analysis

1. A benefit-cost analysis process utilized when all benefits of the alternatives cannot be quantified in terms of dollars. (*U.S. Gen. Account. Off. 1969*)

2. Cost effectiveness analysis compares alternatives in terms of their contribution to a goal by using costs and other effectiveness criteria. (*U.S. Forest Serv. 1974A*)

Also see **Revenue-cost analysis** and **Benefit-cost analysis.**

Cost-revenue analysis. See **Revenue-cost analysis.**

Cost-utility analysis. See **Benefit-cost analysis.**

Cover

1. The proportion of the ground surface under live aerial parts of plants or the combined aerial parts of plants and mulch. (*After Amer. Soc. Range Manage. 1964*)

2. The shelter and protection for fish, wildlife and/or domestic animals. (*After Amer. Soc. Range Manage. 1964*)

The plants or other objects used by wild animals for nesting, rearing of young, resting, escape from predators, or protection from adverse environmental conditions. (*Soil Conserv. Soc. Amer. 1970*)

3. The plants or plant parts, living or dead, on the surface of the ground. (*Hanson 1962*)

Cover type (Plant cover type, Vegetation cover type, Forest cover type)

1. A **forest type** now occupying the ground, no implication being conveyed as to whether it is temporary or permanent—e.g., aspen (type 217), lodgepole pine (type 218).

Differences in state of development are subordinate to differences in species composition for the purposes of distinguishing cover types. (*Soc. Amer. For. 1950 and 1962*)

2. "Cover type" sometimes refers to actual **stands** of any **vegetation type**, whether dominated by tree, shrub, or grass species. (*C.F.S.*)

Cow month

The tenure on range or artificial pasture of a cow for one month. (*Amer. Soc. Range Manage. 1964*)

CPM. See **Critical path method.**

Creep. See **Soil creep.**

Crisis

1. An unstable state of affairs in

which a decisive change is impending. (*Webster 1963*)

2. A psychological or social condition characterized by excessive stress and either endangering or felt to endanger the continuity of the individual or his group. (*Webster 1963*)

Also see **Concern** and **Issue.**

Criteria

1. Regulatory and pollution criteria usages.

A. Measurements which are used to examine the relative degrees of desirability among alternatives or the degree to which a course of action meets an intended objective. (*U.S. Gen. Account. Off. 1969*)

B. The quality level of a resource necessary for it to be acceptable for a specific beneficial use. (*After McGauhey 1968*)

C. A scientific requirement on which a decision or judgement may be based concerning the suitability of a resource's quality to support a designated use. The terms "criteria" and "requirements" can be used interchangeably. (*U.S. Fed. Water Pollut. Control Adm. 1968*)

Unlike regulatory **standards**, "criteria" carry no connotations of more or less subjectively determined, authoritarian decisions as to acceptable resource quality levels. Rather, "criteria" are resource quality levels which have been determined by the accumulation of scientific data showing the relationship between levels of quality and damage to the resource. "Criteria" should be capable of quantitative evaluation by acceptable analytical procedures. Criteria should also be capable of definitive resolution, i.e., their controlling relationship to acceptable quality levels should not be clouded by possible synergisms, antagonisms, or other effects. (*After McKee and Wolf 1963*)

For example, one of the criteria for public drinking water supplies is that

fecal coliform counts have an MPN of not more than 1 per 100 milliliters. This criterion reflects (1) epidemiological evidence on the relationship of **indicator species** (*E. Coli*) abundance to incidence of the waterborne disease typhoid fever, (2) Technical and economic limitations on the ability to sample and measure indicator species abundance, and (3) on technological and economic limitations on the ability of water suppliers to reasonably control the abundance of the indicator species. (*C.F.S.*)

2. Predetermined rules for ranking alternatives in order of desirability to facilitate and expedite the decision-making process. (*U.S. Forest Serv. 1972B*)

3. A rule, or test, by which something can be judged. (*U.S. Forest Serv. 1971*)

Also see **Standard**, definition 2.

Critical area. See **Area of critical environmental concern**.

Critical distance

Environmental psychology usage. The zone which separates "flight distance" (the distance within a **personal space** where an intruder will cause a retreat or flight) and "attack distance"—the distance within a personal space where an intruder will force an animal to feel cornered and attack instead of retreating. (*After Worthington 1974, citing Heidiger 1961*)

Critical path method (CPM)

The CPM (Critical path method) and PERT (Program evaluation and review technique) are network analysis models. Each has its own modeling language, but they differ in only one fundamental respect: CPM seeks to determine the expected times of completion of the total project and times of completion of the subprojects of which it is composed. PERT goes further and seeks to estimate variances associated with these expected times

of completion. (*U.S. Gen. Account. Off. 1969*)

Cropland

Land used primarily for the production of adapted cultivated and close-growing crops for harvest, alone or in association with sod crops, and open land recently in such uses.

In some states land in fruit and nut trees, grapes, etc., is designated orchard land or vineyard land rather than "cropland". (*U.S. Soil Conserv. Serv. 1970 and U.S. Dept. Agric. 1967*) Also see **Agricultural land**.

Cross section (X section)

1. Graphic methods usage. A two-dimensional pictorial representation method which shows the characteristics and relationships between land (and/or water) characteristics that would be observed in a vertical slice through that portion of the earth. (*After Durrenberger 1973*)

2. In land use planning, cross sections frequently only show land surface conditions (soil, soil moisture, vegetation type distributions, elevation slope steepness, etc.), though they may also be used to illustrate subsurface geological structures, groundwater relationships, etc.

The vertical scale of projection is frequently exaggerated in relation to the horizontal to emphasize topographic relationships—e.g., while the scale of horizontal projection may be 1 in = 10 ft, the vertical projection scale may be 1 in = 1 ft. Thus slopes will appear steeper and elevation changes more rapid than they truly are.

This graphical method is frequently used to analyze or show the impacts that would result from potential land uses or use practices on an area, by superimposing over the natural profile the changes in land surface (and/or subsurface) conditions that would result. (*C.F.S.*)

3. Also see **Profile view**.

Crown

The upper part of a tree or other woody plant carrying the main branch system and foliage above a more or less clean stem(s). (*Ford-Robertson 1971*)

CTU. See **Conservation treatment unit**.

Cubic feet per second (c.f.s. or ft³/s)

The amount of water, measured in cubic feet, which flows by a point in a channel (or is discharged from a discharge point) in one second. (*E.C.T.*)

Cultural adaptation

The typically human manner of coping with changes in physical environment and interpersonal relations. Instead of adapting physically to changed conditions, as animals do in order to survive and thrive, human beings modify their common patterns of thought and behavior, especially their technologies. (*O'Connell 1974*)

Cultural change

The modification of a society through innovation, invention, discovery or through contact with other societies. (*Webster 1963*)

Cultural eutrophication

Eutrophication which has been caused by man—i.e., nutrient enrichment of a body of water which stimulates the growth of algae to such abundance that it produces more organic matter than the self-purification processes can overcome. (*After Natl. Acad. Sci. 1969 and Durrenberger 1973*)

Cultural history resource

1. U.S. Forest Service usage. Potential knowledge about human cultural systems, in the form of historic and prehistoric products and byproducts of man. (*U.S. Forest Serv. FSM 2361.05, July, 1973*)

2. "Cultural resource". The physical remains (artifacts, ruins, burial

mounds, petroglyphs, etc.) and conceptual content or context (as a setting for legendary, historic, or prehistoric events, as a sacred area of native peoples, etc.) of an area which is useful or important for making land use planning decisions.

In the land use planning process it is frequently convenient to subdivide the cultural resource category into four parts for inventory and evaluation purposes: (1) "archeological"—resource values associated with former occupancy by native cultural groups; (2) "historical"—values dating from first occupancy by settlers; (3) "religious-cultural groups"—resource values associated with the existence of native people who continue to live in groups practicing the cultural life styles of their ancestors; and (4) "neoteric"—outstanding examples of contemporary culture representing achievements which, in the future, are likely to become historically significant. (*C.F.S.*)

Cultural resource. See **Cultural history resource**, definition 2.

Culture

1. That complex whole which includes knowledge, belief, art, morals, custom and any other capabilities and habits acquired by man as a member of society. (*O'Connell 1974*)

The total pattern of human behavior and its products embodied in thought, speech, action and artifacts and dependent upon man's capacity for learning and transmitting knowledge to succeeding generations through the use of tools, language and systems of abstract thought. (*Webster 1963*)

2. A distinctive, separable bundle of traditions, one that develops historically and is handed down from generation to generation. "Culture" is inherited from the past and has weight and force to determine the content and limits of a group's behavior.

The body of customary beliefs, social forms, and material traits constituting a distinct complex of tradition of a social group with that complex whole including knowledge, belief, morals, law, customs, opinions, religion. Typical behavior or standardized social characteristics peculiar to a specific group. (*Webster 1963*)

3. A fixed pattern of norms or acceptable behavior standards, prescriptions about what one can and proscriptions about what one cannot do in a given society.

Essentially derived from the concept of "custom", this definition over-emphasizes the ways social groups stress and obtain behavioral conformity. (*O'Connell 1974*)

cumulative use

The stream of resource use over time in its aggregate.

The concept "cumulative use" must be sharply differentiated from the concept "rate of use," with the latter referring specifically to units of use per unit of time. (*After Ciriacy-Wantrup 1968*)

unit

Pulpwood measurement term. An equivalent of 100 cubic feet of solid wood. (*Webster 1963*)

Cut

1. The portion of land surface or area from which earth has been removed or will be removed by excavation.

(*Soil Conserv. Soc. Amer. 1970*)

2. The depth below the original ground surface to the excavated surface. (*Soil Conserv. Soc. Amer. 1970*)

3. To lower a land surface by removal of earth materials. (*C.F.S.*)

4. For tree cutting usage see **Cutting**.

Cut and fill

The process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas. (*Soil Conserv. Soc. Amer. 1970*)

Cut-over forest (Logged-over forest)

A forest in which most or all of the merchantable timber has been cut. (*Soil Conserv. Soc. Amer. 1970*)

Cutting (Felling)

The cutting down of standing trees.

"Cutting" is not a synonym for logging or harvesting. These latter terms also include removal of felled trees and some initial processing of the timber prior to removal. (*After Ford-Robertson 1971*)

Cutting cycle (Felling cycle, Cutting interval, Cutting rotation, Felling rotation, Rotation)

The planned, recurring lapse of time between successive major cutting operations in a managed forest. (*After Ford-Robertson 1971*)

CZMA. See Coastal Zone Management Act of 1972.

D

Data

Any recorded measurements, facts, evidence, or observations reduced to written, graphical, tabular, or computer form. The term connotes reliability, and, as such, implies explanation of source, type, precision, accuracy, etc., which permits reliability examination. (*U.S. Forest Serv. 1972B*)

DBH. See Diameter at breast height.

Decision theory

A body of knowledge and related mathematical techniques which have been developed from the fields of statistics, mathematics and logic and which are designed to be of aid in the making of decisions under conditions of uncertainty. (*U.S. Forest Serv. 1972B*)

Decision theory is quite similar to game theory in several respects but a major difference between the two is that in game theory the decision is being made vis-a-vis an opponent, whereas in decision theory the only opponent is nature with its related uncertainty. (*U.S. Gen. Account. Off. 1969*)

Decomposer organism (Decomposer, Reducer, Detritivore)

1. An organism, usually a bacterium or a fungus, that breaks down the bodies or parts of dead plants and animals into simpler compounds. (*Hanson 1962*)

2. Organisms (chiefly bacteria and fungi) which break down the complex compounds of dead protoplasm into simpler substances usable by green plants. Essentially these organisms bring about the mineralization of organic matter. (*Odum 1953*)

For the other two divisions in this particular classification of biotic community organisms, also see **Producer organism** and **Consumer organism**.

Decreaser. See **Decreaser plant species**.

Decreaser plant species (Decreaser)

Range management usage. Plant species of the original vegetation that will decrease in relative amount with continued overuse. (*Amer. Soc. Range Manage. 1964*)

Also see **Invader plant species** and **Increase plant species**.

Deferred grazing. See **Grazing, deferred rotation**.

Deferred rotation grazing. See **Grazing, deferred rotation**.

Degree of use. For range management usage see **Use, degree of**.

Delphi method

A recently developed technique, the purpose of which is to arrive at a consensus regarding an issue under investigation. It consists of a series of

repeated interrogations, usually by means of questionnaires, of individuals whose opinions or judgments are of interest. After the initial interrogation of each individual, each subsequent interrogation is accompanied by information regarding the preceding round of replies. The individual is thus encouraged to reconsider and, if appropriate, change his previous reply in light of the replies of other members of the group. (*U.S. Gen. Account. Off. 1969*)

Demand. See **Demand schedule**.

Demand schedule

The relationship between price and quantity demanded. The demand schedule expresses how much of the good or service would be bought or consumed at various prices at a particular point in time. (*U.S. Gen. Account. Off. 1969*)

Depletion

1. The utilization of a natural renewable resource at a rate greater than the rate of replenishment. (*Webster 1963*)

2. "Depletion" is defined in terms of changes in the time distribution of physical rates of use. By "depletion" is meant the redistribution of use is in the direction of the present, i.e., more use (or emphasis on availability of use) of a resource is to be made for times closer to the present than on use in times more distant in the future (*Ciriacy-Wantrup 1968*)

Derived demand

1. The demand (schedule) for a commodity which grows out of the desire to satisfy the demand for some other commodity. The demand for housing, for example, may create a demand for lumber, bricks, and many other things needed to build the housing. (*Sloan 1961*)

DES. Abbreviation for **Draft environmental statement**. See **Environmental**

impact statement, draft, and discussion in paragraph 2 under Environmental impact statement.

Design

The component of the planning process which controls the actual physical changes that will occur in time and space.

At higher levels of planning, the design component sets the general guidelines for the spatial pattern and physical character of development. At the individual project level design is the activity which sets the precise character, pattern and form of the project environment. (*After Appleyard 1971*)

Design solution (Site planning)

A class of land use planning analytic approaches. The planner/designer generates unique solutions to potential land use conflicts by manipulating the appearance or other physical characteristics of any changes and/or their occurrence in space and time.

"Design solution" potentials are typically evaluated at the individual "project level" or site specific level of any land use planning process. However, this technique can also be used at higher planning levels by examination of the quality of solutions obtained by superimposing design prototypes or current design practices upon the typical site characteristics in a planning area. (*C.F.S.*)

For contrast with **Engineering solution** and **Technological solution**, see **Engineering solution**, definitions 3 and 4.

For an example of a type of design solution planning see **Site planning**.

Desirable plant species

1. Range management usage. Species of moderate to high palatability that are preferred by animals. (*Amer. Soc. Range Manage. 1964*)

2. Species that are beneficial with

respect to soil and water conservation. (*Amer. Soc. Range Manage. 1964*)

Desires. See **Needs**.

Detailed landscape. See **Landscape, detailed**.

Detailed reconnaissance soil map. See **Soil map, detailed reconnaissance**.

Detailed soil map. See **Soil map, detailed**.

Detailed soil survey. See **Soil map, detailed** and **Soil survey**.

Detention storage

The surface runoff which is temporarily present in ground surface irregularities (or even on level surfaces) while it flows overland toward stream channels. (*After Wisler and Brater 1959*)

Deterministic model. See **Model, deterministic**.

Detritivore. See **Detritivore**.

Detritivore (Detritivore)

An organism (plant or animal) that feeds on the organic remains or other organic debris from **autotrophic** (mostly plant) **organisms**. (*After Odum 1971*)

Developed recreation area. See **Recreation area, developed**.

Developer

Usage in the defeated 1973 bill for a national **Land Use Policy and Planning Assistance Act**. Any person or persons who directly or indirectly, through any formal or informal combination or aggregation, own or control a tract or tracts of land for which such person or persons propose a project.

"Person" includes any individual, partnership, corporation, association, unincorporated organization, trust, estate, or any other legal or commercial entity, except Federal, state or local government agencies.

This definition is designed to make

certain that individuals cannot establish dummy corporations, trusts, or otherwise organize in a manner to avoid the size and time period limitations of the definition of projects (such as using an organizational arrangement to hide the separating of tracts into two areas comprising more than twenty-five, but less than fifty, units; the selling or developing of two such tracts which are functionally interrelated but separated by a short distance; selling or developing one such tract, waiting a few years, and developing a second tract). (*U.S. Congr., Senate, Com. Inter. Insular Aff.* 1973)

Development

1. A built-up tract of land, especially used in the sense of a subdivision having the necessary utilities—i.e., water, gas, electricity, roads, etc. (*After Webster* 1963)

2. In planning, the term “development” is typically used when referring to intensive build-up types of land uses—i.e., uses predominantly consisting of buildings, paved areas and other types of site alterations. “Development” in that sense utilizes the **land** only as a location, not for its **natural** resource properties.

“Development” is sometimes broken into broad use type categories—such as residential, commercial, industrial, etc. (*C.F.S.*)

Development planning

Development planning is most commonly used in the context of planning for economic growth and technological development in undeveloped regions or countries. Planning in these settings involves not only creation of a strategy for resource development and allocation, but also creation of the **infrastructure** and **social institutions** necessary for implementation of the physical and economic features of such a plan. (*C.F.S.*)

Also see **Extraordinary planning** and **Comprehensive plan**, definition 3

Development rights

A broad range of less-than-fee **simple ownership** interests. It includes mainly various forms of the **easement** a clearly defined property right. The landowner keeps the title but agrees to continue using the land as in the past, the right to develop the land resting in the holder of the easement. (*U.S. Bur. Outdoor Recreation* 1974)

Development rights, acquisition of

A plan implementation technique which ensures conformity of land use to the plan by purchasing for public ownership the landowner's right to use his land for certain types of potential land uses—such as subdivision housing or industry.

The originating concept was that total public ownership was undesirable and typically fiscally unfeasible. The purchase of only selected **property rights** would be substantially less expensive than total purchase and would still allow the owner to continue making other economic uses of his land. However, in practice public acquisition of development rights has often cost up to 95 percent of the full **market value** of land. (*C.F.S.*)

Also see **Taking**.

Development rights, transfer of

A method of separating and marketing the **development rights** of a property. Owners of developable property can buy rights to develop more intensively while the transferring property is preserved open or less developed. (*U.S. Bur. Outdoor Recreation* 1974)

Development type

Those **land use types** by which the formerly **open spaces** of an area are prominently altered or made to appear built-up—i.e., buildings, paved areas, and other types of site alterations.

"Development" is sometimes broken down into such broad type categories as residential, commercial, and industrial. (*C.F.S.*)

Development zoning. See **Zoning, development.**

Diagrammatic representation (Blob diagram, Schematic diagram)

A land use planning analytical technique in which the physical components (such as parking lots, lavatories, garbage cans, picnic tables, beaches, etc.) in a plan are represented symbolically, usually just by their names written inside individual circles. The relationships between components are then represented by lines connecting those which have necessary or desirable support functions. The individual components are then shifted so as to minimize the extent to which different interconnecting lines cross each other. The resulting solution is assumed to represent the most efficient spatial relationship between project components, and thus represent the idealized goal of the actual physical plan.

While this technique is usually utilized at the project or site planning level, there is no conceptual reason why it cannot also be used for studying the optimal relationships between the more vaguely defined components of the broader levels of land use planning. (*C.F.S.*)

Diameter at breast height (DBH)

The diameter of a tree measured four feet, six inches from the ground level. "Ground level" can follow two conventions; either the highest point of the ground touching the stem, or the mean of the highest and lowest points. (*Ford-Robertson 1971*)

Direct effect (Primary effect)

A condition caused by an action or inaction without an intermediary causal agent; an effect characterized

by a close causal relationship. (*After Webster 1963*)

Disadvantaged groups

Lacking in the basic resources or conditions (as standard housing, medical and educational facilities, civil rights) believed to be necessary for an equal position in society. (*After Webster 1963*)

The current term used by the Federal government for what has in the past been called "poor" and "underprivileged". It covers more than the economic conditions associated with "poor" and does not have the implication of social or economic oppression contained in "underprivileged." (*E.C.T.*)

Discharge

The volume of water flowing past a point per unit time, commonly expressed as cubic feet per second, million gallons per day, gallons per minute or cubic meters per second. (*Soil Conserv. Soc. Amer. 1970*)

Discontinuous easement. See **Easement, discontinuous.**

Discounting

The practice of placing a lesser value (economic or other) on future events than on present events for the purpose of comparison. An item received today is seen to be worth more than an identical item received next year. Discounting refers only to the timing of an event and should not be confused with reduced values based on the uncertainty of future events nor implied quality changes over time. (*E.C.T.*)

Discount rate

The interest rate used in plan formulation and evaluation for **discounting** future **benefits** and computing **costs**, or otherwise converting benefits and costs to a common time basis. (*U.S. Dept. of Agric. 1974*)

Also see **Discounting.**

Disjointed incrementalism. See **Incrementalism.**

Dispersed recreation. See **Recreation, dispersed.**

Dissolved oxygen (D.O.)

1. The oxygen dissolved and freely available in water. (*After Wash. State Univ. Coop. Ext. Serv. 1972*)

2. The oxygen dissolved in water, waste water, or other liquid and usually expressed in milligrams per liter, **parts per million**, or percent of saturation. (*Amer. Public Health Assoc., et al. 1969*)

Dissolved oxygen concentration (Dissolved oxygen level, DOL)

The amount of oxygen dissolved in a water sample expressed in **parts per million**. (*Sesco, et al. 1973*)

In unpolluted water dissolved oxygen is usually present in amounts of 10 parts per million or less. Adequate dissolved oxygen is necessary for the life of fish and most other aquatic organisms. About 3 to 5 parts per million is the lower limit needed for the support of fish life over a long period of time. (*Wash. State Univ. Coop. Ext. Serv. 1972*)

Dissolved oxygen level. See **Dissolved oxygen concentration.**

Dissolved solids

1. The total amount of dissolved material, organic and inorganic, contained in water or wastewater. (*Wash. State Univ. Coop. Ext. Serv. 1972*)

2. The solid matter that remains after a filtered volume of water has been evaporated. The amount of residue is commonly expressed as a proportion of the original sample in **parts per million** parts of the original. (*Sesco, et al. 1973*)

Diversity index. See **Species diversity index.**

DO. See **Dissolved oxygen.**

DOL. See **Dissolved oxygen concentration.**

Dominant

The land against which an easement or privilege exists is called the **servient tenement** and the estate to which it is annexed is the **dominant tenement** and their owners are called respectively **servient** and **dominant owner**. (*U.S. Bur. Outdoor Recreation 1974*)

Also see **Easement.**

Dominant use

A concept in which land and water resources are classified and managed for one main type of use. Other use may or may not be excluded but are always of secondary importance to the optimum development for the dominant use. (*Sesco, et al. 1973*)

Also see **Dominant use management.**

Dominant use management

Management based on the idea that although land may be capable of many uses it will provide for one use better than any other. The land is managed for the single purpose of maximizing that use to the exclusion of other use where conflicts exist.

Devoting each land unit to the use it best provides for is assumed to be the most efficient allocation of resources. This assumption has been shown to be erroneous by the science of **operations research**, among others. Dominant use management is prohibited on the National Forests under the **Multiple Use-Sustained Yield Act** (*E.C.T.*)

Draft environmental impact statement
See **Environmental impact statement draft.**

Draft environmental statement. See **Environmental impact statement, draft** and discussion in paragraph 2 under **Environmental impact statement.**

Drainage basin. See **Watershed.**

Durability (Environmental durability)

1. The quality or state of being resistant to breakage or destruction. (*After Webster 1963*)

2. In a land use planning context, the relative ability of resources to tolerate sustained use, without degradation of the resource base (i.e., lowering productivity or desirable resource quality). This ability is sometimes rated on a qualitative scale extending from "fragile" to "durable".

"Durability" ("Environmental durability") in land use planning refers to those resource types or properties which are resistant to degradation in the presence of whatever types of use are considered by the evaluation process. For example, vegetated sand dunes may be classed as "environmen-

tally fragile" for off-road vehicle uses while unvegetated dunes are "environmentally durable". (*C.F.S.*)

Duration curve. See **Flow duration curve.**

Dynamic programming

In a multistage decision process, a systematic method for searching out that sequence of decisions which maximizes or minimizes some predefined objective function.

The method is based on Bellman's Principle of Optimality which states that "an optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision." (*U.S. Forest Serv. 1972B*)

E

EAR. See **Environmental analysis report.**

Easement

1. An interest in the land of another which allows the easement holder specified uses or rights without actual ownership of the land. (*U.S. Bur. Outdoor Recreation 1974*)

2. The right of the owner of one parcel of land, by reason of such ownership, to use the land of another for a special purpose not inconsistent with general property ownership. The land against which the easement or privilege exists is called the **servient tenement** and the estate to which it is annexed is the **dominant tenement** and their owners are called respectively "servient" and "dominant" owner. (*U.S. Bur. Outdoor Recreation 1974*)

3. The legal right to use the land of another for a precise and definite purpose. (*Sesco, et al. 1973*)

Easement, affirmative

An interest in land which gives a person or agency the right to do something on the land, such as hiking, fish-

ing, flooding, etc. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, conservation

A group of negative and affirmative easements... [that] pertain to keeping land in open use or a natural state, or provide some other conservation or recreation function. These include scenic, flooding, and agricultural easements.

An easement to assure the permanent preservation of land in its natural state or in whatever degree of naturalness the land possesses at the time the easement is granted.

An easement that may include one or more of the following provisions: (1) prohibitions against erecting buildings or other structures; (2) restrictions against constructing or altering any private drives or roads; (3) prohibitions against the removal or destruction of trees, shrubs, or other greenery; (4) restrictions against uses other than residential or agricultural, for public utilities, and existing uses; (5) restrictions against the display of

outdoor signs, billboards or any other form of outdoor advertising; (6) prohibitions against dumping or storage of trash, wastes or unsightly or offensive materials of any kind; (7) other kinds of restrictions consistent with open space preservation and reservation. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, continuing

An easement which is self-perpetuating, independent of human interventions, as the flow of a stream, or one which may be enjoyed without any act on the part of the persons entitled thereto. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, discontinuous (Noncontinuous easement, Nonapparent easement)

An easement, the enjoyment of which may be had only by the interference of man, as a right-of-way or a right to draw water. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, negative

An interest in land which can give the easement-owner the right to prevent the owner of the land from doing something on it. **Scenic easements** are of this type. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, recreational

Affirmative easements allowing public entry on the servient land to hunt, fish, or enjoy other recreational activities. (*U.S. Bur. Outdoor Recreation 1974*)

Easement, scenic

Essentially an easement of view. Scenic easements restrict the use of land adjacent to public highways, parks, and rivers. They may provide something attractive to look at within the easement area, an open area to look through to see something attractive beyond the easement itself, or a screen to block out an unsightly view beyond the easement area. (*U.S. Bur. Outdoor Recreation 1974*)

Ecoclass

U.S. Forest Service usage. Classification system for the biological and earth sciences based on linking together existing disciplinary classifications of the major ecosystem components. It is a unifying framework for linking three basic biological and earth science stratifications or classifications—the vegetation subsystem, the land subsystem, and the aquatic subsystem. A hierarchical structure is given in which the lowest level units are the “ecological land unit” (ELU), a composite of the land and vegetation subsystems, and the “ecological water unit” (EWU), a composite of elements of the land and aquatic subsystems. (*After Corliss 1974*)

Also see **Ecological land unit** and **Ecological water unit**.

Ecological determinism

A particular point of view in planning which advocates that retention of natural elements and processes should be given priority in planning. Natural elements (such as **aquifers**, wildlife breeding areas, and flood plains) which are valued by segments of society or freely perform necessary life support or **quality of life** functions, or whose alteration will significantly damage other valued resources, should be protected on plans and in plan policies.

Ecological determinism is essentially a synonym for **physiographic determinism**, **biological primacy**, and **biophysical determinism**. Although “ecological” strictly implies concern with organisms and their environmental relationships, “ecological determinism” also applies to such nonliving environmental elements as **aquifers**, steep slopes, and severe storm impact zones. (*C.F.S.*)

Ecological land unit (ELU)

1. U.S. Forest Service usage. One of the lowest levels of the “Ecoclass”

system of classifying ecosystems into subdivisions for forest description and management. An ELU is a composite of elements from the land subsystem and vegetation subsystem which together define a homogeneous unit. (*After Corliss 1974*)

2. U.S. Forest Service Resource Capability System (RCS) usage. Units of land having strong uniformity in slope steepness; aspect; microclimate; rock types and conditions, geomorphology, soil characteristics and productive capabilities, type, density and age of vegetation and ground cover, and drainage characteristics.

The basic physical unit of land that scientific disciplines agree must be delineated and examined as a separate entity (for use evaluation or management purposes).

The basic unit that is used in the analysis of onsite potentials, capabilities and limitations. The most significant level of land stratification which best communicates the basic (inherent) capabilities and limitations. (*Reid 1972*)

Land (or water) units which because of their strong uniformity in physical and biological characteristics respond similarly to management activities or other stimuli. Sometimes called "response units". (*H.G.*)

Also see **Ecoclass**, **Ecological water unit** and **Homogeneous response unit**.

ecological water unit (EWU)

U.S. Forest Service usage. One of the lowest levels of the "Ecoclass" system of classifying ecosystems into subdivisions for forest description and management. An EWU is a composite of elements from the land and aquatic subsystems, where aquatic type and the adjacent land types together define a homogeneous unit. (*After Corliss 1974*)

Also see **Ecoclass**, **Ecological land unit**, and **Homogeneous response unit**.

Ecologic community. See **Biotic community**.

Ecologic competition. See **Competition**.

Ecologic diversity. See **Biologic diversity** and **Species diversity**.

Ecologic indicator. See **Indicator, biologic**.

Ecologic niche. See **Niche**, definition 2.

Ecologic pyramids

Groups of organisms in nature often consist of many small organisms associated with a few larger organisms. This distribution of number and size has been compared to a pyramid with a broad base representative of the numerous small organisms and the point of the pyramid representing the few largest organisms.

There are three ecological pyramids which result from food and energy relationships: the **pyramid of numbers**, the **pyramid of biomass** and the **pyramid of energy** or food production rates. (*Odum 1953*)

Ecologic stability (Balance of nature)

An ecological system may be said to be stable during that period of time when no species becomes extinct (thereby creating a vacant niche) and none reaches plague proportions for long enough to destroy the niches of other species and cause them to become extinct.

A stable ecosystem is one in which all niches are fully occupied by appropriate species.

Whatever stability there is in the ecological world is not a static equilibrium, but a fluctuating or dynamic one, and normally a highly fluctuating one. Stability lies in the ability to bounce back, not in the ability to hold tenaciously to ground once taken or numbers once achieved. (*Preston 1969*)

Also see **Balance of nature**.

Ecologic succession. See **Succession**.

Ecology

A branch of science concerned with the interrelationships of organisms and their cycles and rhythms, community development and environments—especially as manifested by natural structure, interaction between different kinds of organisms, geographic distributions, and population alterations. (*After Webster 1963*)

Econometrics

The testing and quantifying of economic theories and the solution of economic problems by their conversion to mathematical forms, application of mathematical processes and the use of statistical techniques. (*After Webster 1963*)

Economic analysis

An analysis of the economic effects of a given action. It includes measurement of all pertinent desirable and undesirable consequences to all segments of the economy stated in comparable quantitative monetary terms. It also includes an objective or subjective analysis of factors not quantifiable in monetary terms. (*P.M.R.*)

Economic base analysis. See **Export base analysis.**

Economic depletion. See **Depletion.**

Economic determinism

1. A point of view which advocates that planning decisions should be based primarily upon the results of analysis of changes in resource supply and demand in response to changes in the "price" for the right to use a resource. That potential user or use which is willing or able to give up the most wins the use rights. Maximizing the total economic welfare is considered to result in the maximization of the benefits to society from resource use allocation and this is viewed as being the goal of all resource use. (*C.F.S.*)

The total economic welfare will be

maximized by providing the resources to the highest bidders in such quantities that the price individuals are willing to pay exactly equals the cost of providing the last unit of the resource, under standard economic assumptions. (*E.C.T.*)

2. The view that economic factors are the only causes of social patterns.

3. The view that economic factors are fundamental or dominant, despite the simultaneous importance of biological, psychological, political, cultural, and social factors. (*O'Connell 1974*)

Economic enterprise (Economic unit)

Range management usage. A ranch business of sufficient resources to provide an acceptable standard of living for a family. . . . Often termed an economic unit, but this is considered erroneous because a "unit" is a subdivision of a management area. (*Amer. Soc. Range Manage. 1964*)

Also see **Management area** and **Management unit.**

Economic externalities

1. Effects of resource allocation decisions which are not included in the market mechanism, and as such have no economic influence on resource allocation decisions; failures of the market mechanism as a resource allocation tool. (*E.C.T.*)

2. A cost or benefit that occurs whenever the activities of one or more persons affect the welfare or production functions of others who have no direct control over that activity. (*Sesco, et al. 1973*)

Economic growth

Increased economic activity in real terms over time. This does not necessarily correspond to increased production of physical goods. (*E.C.T.*)

Economic life

That period of time extending from the date of installation [of a facility]

into service to that date when the facility is no longer economically profitable to use. (*Winfrey and Zellner 1971*)

Also see **Physical life**.

Economic scarcity (Resource scarcity)

The condition whereby a limited number of marketable goods are desired in higher quantities than available. The "scarcity" can be eliminated either by increasing the supply of available goods and maintaining a low price, or by raising the price of the goods until the number of people willing to pay the higher price is reduced to the supply level. Which is the socially superior method depends on supply costs and the existence of **economic externalities**. (*E.C.T.*)

Economic subregion

U.S. Bureau of the Census usage. These areas represent combinations of **state economic areas**. The 510 state economic areas in the 1970 U.S. Census are consolidated into a set of 121 economic subregions which cut across state lines but which, as intended, preserve to a great extent the homogeneous character of the state economic areas. (*U.S. Bur. Census 1971*)

Economic unit. See Economic enterprise.

Ecosystem (Bioc(o)enosis, Bioc(o)enose, Biogeoc(o)enosis, Biogeoc(o)enose)

1. The system formed by the interaction of a group of organisms and their **environment**. (*Durrenberger 1973*)

2. A complete, interacting system of organisms considered together with their environment, e.g., a marsh, a **watershed**, a lake, etc. (*After Hanson 1962*)

3. An ecological community considered together with the nonliving factors of its environment as a unit. (*Webster 1963*)

4. Any spatial unit that includes all of the organisms (i.e., the **biotic com-**

munity) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined food and feeding relationships, **biologic diversity** and **biogeochemical cycles** (i.e., exchange of materials between living and nonliving parts) operating as an integrated system.

"**Ecosystem**" is the preferred term in English while "biocoenosis" or "biogeocoenosis" is preferred by writers using or familiar with the Germanic and Slavic languages. (*After Odum 1971*)

Some (*Ford-Robertson 1971, Hanson 1962*) make a distinction between the two terms by using **bio(geo)-coenosis** to refer to actual biological units (such as a certain bog) and "ecosystem" when referring to conceptual units. Others (*Odum 1971*) make no such distinction. We prefer Odum's lumping of the terms, while recognizing that in some technical, ecological literature the distinction is significant. (*C.F.S.*)

5. Any complex of living organisms taken together with all the other biotic and abiotic factors which affect them, that are mentally isolated for purposes of study. (*After Ford-Robertson 1971, citing Tansley*)

Ecotone

An ecotone is a transition between two or more **biotic communities**.

It is a junction zone or tension belt which may have considerable linear extent but is narrower than the adjoining community areas themselves.

The ecotonal community commonly contains many of the organisms of each of the overlapping communities and, in addition, organisms which are characteristic of and often restricted to the ecotone. Often, the number of species in the ecotone is greater than in the communities flanking it. Organisms which occur primarily or most abundantly or spend the greatest

amount of time in junctional communities are often called "edge species". (*Odum 1959*)

Ecotype (**Geographical race**, **Habitat type**)

1. A locally adapted population of a species which has a distinctive limit of tolerance to environmental factors. (*Soil Conserv. Soc. Amer. 1970*)

2. A genetically uniform population of a species resulting from natural selection by the special conditions of a particular **habitat**. (*Ford-Robertson 1971*)

Edaphic

Pertaining to the soil. (*Marsh 1964*)

Edaphic climax. See **Climax community**, definition 3.

Edaphic factor (**Soil factor**)

A characteristic or factor of the soil environment which limits the development or existence of an organism or **biotic community**.

For example, low nutrient or micro-nutrient concentrations, or the presence of toxic concentrations of certain substances, or insufficient or excess soil moisture conditions are typical edaphic factors. (*Marsh 1964*)

Especially used to refer to soil factors as opposed to **physiographic** or climatic factors. (*Sesco, et al. 1973*)

Edge

Visual terminology usage. The linear elements in a view which are noted (or considered by the observer) as being the dividing lines between major components of a scene. "Edges" serve as visual boundaries—such as land-water boundaries or forest-meadow boundaries. (*After Litton 1966*)

Edge species. See **Species**, **edge**.

Effectiveness-cost analysis. See **Cost-effectiveness analysis**.

Effectiveness index

The index used in cost-effectiveness

analysis. (*E.C.T.*)

See **Cost-effectiveness analysis**.

Effectiveness test

U.S. Water Resources Council (WRC) usage. One of the tests to be applied in choosing among alternatives in planning for water and related land resources while following the WRC **Principles and Standards**.

The "effectiveness test" refers to technical performance of the plan and the level of contribution to the components of the objectives. (*U.S. Dep. of Agric. 1974*)

Efficiency test

U.S. Water Resources Council (WRC) usage. One of the tests to be applied in choosing among alternatives in planning for water and related land resources while following the WRC **Principles and Standards**.

The "efficiency test" requires that among all acceptable alternatives (Federal and non-Federal, water and non-water, structural and nonstructural) the given alternative plan should be the least cost means, considering all adverse effects, of achieving specified components of the objectives when comparably evaluated according to these standards. (*U.S. Dep. of Agric. 1974*)

Effluent

The liquids discharged from domestic, industrial and municipal waste collection systems or treatment facilities. (*Soil Conserv. Soc. Amer. 1970*)

Egalitarianism

1. A belief that all people are equal in intrinsic worth and are entitled to equal access to the rights and privileges of their society. (*Webster 1963*)

2. A social philosophy advocating the leveling of social, political and economic inequalities. (*Webster 1963*)

As an ideology, it holds that equality in various specified aspects of social life and organization is just and

proper and should be a goal in the redesign of social institutions.

Exactly what aspects of social reality are considered in order to decide what should be equal and what unequal is a rather complex problem that sometimes involves self contradictions; for example, equality of opportunity can result in unequal distributions, because people have different abilities, degrees of motivation, and luck; equality of resource inputs in different schools may result in inequality in educational achievements of the students, if the latter began with unequal advantages, and attempting to equalize output of student achievement from different schools might require unequal resource inputs in order to overcome the initial handicaps of some students. (O'Connell 1974)

EIS. See **Environmental impact statement.**

Elasticity

In economics, a measure of the responsiveness of the quantity demanded or supplied to changes in price. Elasticity measures the degree to which price is effective in calling forth or holding back quantity. (U.S. Gen. Account. Off. 1969)

Element. See **Plan element** or **Program element.**

Elites

The individuals at the top of any stratification hierarchy, such as economic, social prestige, or political.

The term "power elite" implies a high degree of coordination and a set of common interests among those in top corporate and governmental positions. (O'Connell 1974)

Also see **Social class.**

Elitism. See **Pluralism.**

ELU. See **Ecological land unit.**

Eltonian pyramid. See **Pyramid of numbers.**

Eminent domain

1. The right or power of government subject to constitutional and statutory limitations to take private property for public use upon making **just compensation.** (U.S. Bur. Outdoor Recreation 1974)

2. The legal right of public agencies to claim private property for public use, if compensation is made to the owner for property so claimed. The use of this power is limited by the "Due Process of the Law" clause in the 14th Amendment of the United States Constitution. (Sesco, et al. 1973)

Also see **Taking, Police power, Just compensation.**

Enclosing landscape. See **Landscape, enclosing.**

Endangered species. See **Species, endangered.**

Endangered Species Act of 1973 (PL 93-205; 87 Stat. 884)

Repeals and replaces the Endangered Species Conservation Act of 1969. An act to provide a means whereby ecosystems upon which **endangered species** and **threatened species** depend may be conserved, to provide a program for the **conservation** of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the (relevant) treaties and conventions. . . . (Endangered Species Act of 1973)

Also see **Conservation, definition 3.**

Endangered Species Conservation Act of 1969

Now repealed and replaced by the **Endangered Species Act of 1973.**

Endemic organism

A taxonomic category (e.g., genus, species, variety) whose natural occurrence is confined to a certain region and whose distribution is relatively limited. (After Hanson 1962)

Also see **Native organism**. Contrast with **Species, exotic**; **Species, feral**; **Species, naturalized**; and **Species, resident**.

Endemic species. See **Endemic organism**.

Energy resource planning

Functional planning for the development and use of energy resources. (*E.C.T.*)

Also see **Functional planning**.

Engineering solution

1. The actual application of technical solutions to solve (or at least minimize) problems associated with particular **land uses** or **land use practices**. (*C.F.S.*)

2. The use of technical knowledge to implement a project by minimizing its land use problems. (*After Webster 1963*)

The distinction between **technological solutions**, and "engineering solutions" is that the first refers just to the development of new technical means for providing solutions whereas the second applies to the application of any technical solution (new or old) to solve the potential problems.

The distinction between "engineering solutions" and **design solutions** is that the second minimizes potential conflicts by manipulating size, shape, appearance, and placement whereas the first utilizes technical solutions.

For example, an engineering solution to stabilizing a stream bank against erosion by increased runoff might be to line certain portions of the channel with concrete. A "design solution" to such a potential problem would be minimization of use of impervious pavings by projects or redirection of such increased runoff into high-infiltration-rate, heavily vegetated portions of the site. (*C.F.S.*)

Environment

1. The complex of climatic, soil and biotic factors that act upon an organism or ecological community and

ultimately determine its form and survival. (*Holland 1970*)

2. Something that surrounds; surroundings.

All the conditions, circumstances, and influences surrounding and affecting the development of an organism or group of organisms. (*U.S. Forest Serv. 1971*)

3. The aggregate of all the external conditions and influences affecting the life and development of an organism, society, etc. (*After Webster 1963*)

Also see **Habitat**.

Environmental analysis. See **Environmental impact analysis**.

Environmental analysis report (EAR)

A report on environmental effects of proposed Federal actions which may require an **Environmental impact statement** (EIS) under section 102 of the **National Environmental Policy Act** (NEPA). The EAR is an "in-house" document of varying degrees of formality which becomes the final document on environmental impacts for those projects which, because their effects are minor, do not require a formal EIS. Although not formally prescribed under NEPA, the EAR is the document normally used to determine whether section 102 of NEPA applies to the project in question, and as such is subject to court challenge if no EIS is filed. (*E.C.T.*)

Also see **Environmental impact statement, final**.

Environmental assessment. See **Environmental impact analysis**.

Environmental corridor (Buffer, Buffer strip, Buffer zone)

1. A strip of land designed to protect the natural environment of an area and to prevent undesirable encroachment such as commercial development along a stream. (*Sesco, et al. 1973*)

Also see **Buffer**.

Philip Lewis' usage. The linear pattern identified in the typical midwestern landscape by combining maps of the major natural environmental elements of importance for recreation (rivers, lakes, wetlands and significant relief) with man-made features having recreational value (e.g., historic sites). (*After Belknap and Furtado 1967*)

Environmental durability. See **Durability.**

Environmental fragility. See **Fragility.**

Environmental hazard. See **Natural hazard.**

Environmental impact analysis (Environmental analysis, Environmental assessment, Environmental impact assessment)

1. An activity that involves the consideration of the interaction of physical, natural, social and economic factors and a determination of probable effects of the plan or proposal upon these operating systems. (*U.S. Forest Serv., FSM 8310.5, Oct. 1973*)

2. A process that generates knowledge of environmental and ecological impacts, and evaluates their consequences before activities are undertaken. (*Hevman and Twiss 1971*)

3. An evaluation and objective prediction of the environmental impacts of a proposed action using a systematic, interdisciplinary approach that integrates social and natural sciences and environmental design arts. (*After National Environmental Policy Act*)

Environmental impact assessment. See **Environmental impact analysis.**

Environmental impact statement (EIS, 102 statement, Environmental statement)

A document prepared by a Federal agency in which anticipated environmental effects of a planned course of action or development are evaluated. A Federal statute (section 102 of the National Environmental Policy Act of

1969) requires that such statements be prepared. It is prepared first in draft or review form, and then, in a final form. An impact statement includes the following points: (1) the environmental impact of the proposed action, (2) any adverse impacts which cannot be avoided by the action, (3) the alternative courses of action, (4) the relationships between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, (5) a description of the irreversible and irretrievable commitment of resources which would occur if the action were accomplished. (*Sesco, et al. 1973*)

Although "environmental impact statement" (EIS) is the popularly used term, some prefer the term "Environmental statement" (ES), feeling that EIS is an inaccuracy due to the negative connotations of the word "impact". Section 102(C) of NEPA mentions that impacts, effects, alternatives, etc. will be contained in the required "detailed statement". Consequently, to name one feature and to exclude others is inaccurate. Thus the draft is the DES and the final statement the FES. (*After J.Z.*)

Environmental impact statement, draft (DEIS, Draft environmental statement, DES)

The version of the statement of environmental effects required for major Federal actions under section 102 of the National Environmental Policy Act (NEPA), and released to the public and other agencies for comment and review. It is a formal document which must follow the requirements of NEPA, the Council on Environmental Quality (CEQ) Guidelines, and directives of the agency responsible for the project proposal. Since the adoption of state and local laws modeled after NEPA, this term has also been used to refer to similar statements required to comply with those

laws. (*E.C.T.*)

Also see **Environmental impact statement** and **Environmental impact statement, final**.

Environmental impact statement, final (EIS, Final environmental statement, FES)

The final version of the statement of environmental effects required for major Federal actions under section 102 of the **National Environmental Policy Act (NEPA)**. It is a revision of the draft environmental impact statement to include public and agency responses to the draft. It is a formal document which must meet legal requirements and is the document used as a basis for judicial decisions concerning compliance with NEPA. This term is also used for similar statements prepared to comply with state and local laws patterned after NEPA. (*E.C.T.*)

Also see **Environmental impact statement** and **Environmental impact statement, draft**.

Environmental index. See **Index**.

Environmental modification

Deliberate or unintentional changes produced by man in the external conditions that act upon an organism or community to influence its development or existence. (*After T.E.A.*)

Environmental planning

Planning which considers the environment not only in terms of physical configurations, location and space but also in terms of direct experiential and sensory surroundings as a primary source of living experience, and as a primary conditioner of physical and psychological development for each individual human being.

Planning which recognizes the environment as a physical and biological system, with its own natural and technological characteristics and processes.

Planning which is concerned with human activities taking place in the

outdoor environment and which reconciles their demands for and impacts upon the outdoor environment.

Planning which seeks to ensure that policies, programs, designs and actual developments incorporate forecasts of the effects upon environmental amenity and ecology so as to anticipate and evaluate the consequences of decision in light of present and future values at stake. (*Appleyard 1971*)

Environmental psychology

That area of psychology which deals with environmentally induced behavior or mental states of individuals or groups, e.g., whereas psychoanalysis probes for subconscious motivations derived from past experience, or behavioral psychology attempts to alter self concepts through operant conditioning, environmental psychology seeks to determine how the everyday physical environment affects human behavior.

Also, the study of human perception of elements in the environment or of different types of environmental settings. Perception in this context is understood to mean not only direct sensory knowledge but also cognitive discrimination expressed in terms of preferences rated on a scale of desirability vs undesirability. (*L.W.*)

Environmental quality

1. Natural environmental quality. Heyman and Twiss in evaluating management practices on the Federal public lands speak of "environmental quality" as referring "primarily to the continuance, to the extent feasible, of the natural ecosystems existing on public lands especially as that ecosystem is important to human health and safety, the provision of direct sensory experiences, and the continued viability of life forms and **biotic communities** that exist naturally on, and surrounding, the public lands." (*Heyman and Twiss 1971*)

2. In general, definition 1 must be expanded to include all **environments** experienced by man and include aspects of **environmental psychology**. Even though qualities may exist without man, it is man who makes the judgments that define qualities. The qualities are both individual and consensus. The "group" may attach some value or measure of quality to some environment, and each individual may give a somewhat different value to the same environment. "Quality" is a "separate reality" for each individual, but may contain universals for a great many individuals. Thus, the environment may be a wilderness or a city street, with each person having his or her own value judgment as to the quality of the environment, but together they may reach a consensus which forms an "environmental quality" basis for planning. (*After A.W.M.*)

3. U.S. Water Resources Council (WRC) usage. Enhancing environmental quality by the management, conservation, preservation, creation, restoration or improvement of the quality of certain national and cultural resources and ecological systems is one of the two main objectives for programs involving water and related land resources administered by Federal agencies whose activities involve planning and development of water resources, as contained in the Water Resources Council **Principles and Standards**.

An evaluation of environmental quality effects should include: (1) areas of natural beauty; (2) water, land, and air quality; (3) biological resources and selected ecosystems; (4) geological, archeological, and historical resources; and (5) irretrievable commitments of resources to future use. (*After U.S. Dep. of Agric. 1974*)

4. One of the four "required accounts" for categorizing, displaying, or "accounting" the beneficial and adverse effects of each alternative plan

formulation for water and related land resources planning specified in the Water Resources Council's **Principles and Standards** and the U.S. Department of Agriculture's "Procedures" for adhering to them. (*After U.S. Dep. of Agric. 1974*)

5. The sum total of the forces and factors which influence people's satisfactions with their work, leisure, living conditions and community. (*Barron 1972*)

Environmental Quality Improvement Act of 1970 (83 Stat. 852; 42 U.S.C. 4371-4374)

Assures that each Federal department and agency conducting or supporting public work activities which affect the environment shall implement the policies established under existing law; and authorizes an Office of Environmental Quality, which shall provide the professional and administrative staff for the Council on Environmental Quality. (*After U.S. Forest Serv. 1974*)

Environmental quality index. See **Environmental quality and Index**.

Environmental setting. For U.S. Forest Service usage see **Management situation**.

Environmental statement. See discussion in paragraph 2 under **Environmental impact statement**.

Environmental system

An arbitrarily defined set of interacting components in the environment, understood to have some degree of unitary integrity. (*L.W.*)

Environment, human

The aggregate of all the external conditions and influences affecting the life and development of an individual, society, etc. (*After U.S. Forest Serv., F.S.M. 8310.5, Oct., 1973*)

Ephemeral stream

1. A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from snow or other sources. Its channel is at all times above the water table. (*Soil Conserv. Soc. Amer.* 1970)

2. The term may be arbitrarily restricted to streams which have no-flow periods of one month or longer. (*Amer. Geol. Inst.* 1962)

3. In areas where precipitation almost totally consists of rainfall, the term is commonly used to refer to the short-lived streams which flow for only a very short time (a few days at most) after each storm event. (*C.F.S.*)

4. They have no permanent or well-defined channels but follow slight depressions in the natural contour of the ground surface. (*Wisler and Brater* 1959)

Also see **Intermittent stream** and **Perennial stream**.

Erosion

The group of processes whereby earthy or rock material is worn away, loosened or dissolved and removed from any part of the earth's surface. It includes the processes of weathering, solution, corrosion and transportation. (*Amer. Geol. Inst.* 1962)

"Erosion" is often classified by the eroding agent (wind, water, wave, or raindrop erosion) and/or by the appearance of the erosion (**sheet**, **rill**, or **gully erosion**) and/or by the location of the erosional activity (**surface**, or **shoreline**) or by the material being eroded (**soil erosion** or **beach erosion**).

Relations between erosion terms: "raindrop erosion" always takes the form of "sheet erosion"—though "sheet erosion" can also be caused by wind action or the movement of thin sheets of water over the ground surface. "Sheet", "gully" and "rill erosion" are all forms of "soil erosion".

"Sheet" and "rill erosion" are the two forms which "surface erosion" may take. "Beach erosion" is always "shoreline erosion"—though, because not all shorelines are beaches, "shoreline erosion" is not always "beach erosion". The term **accelerated erosion** is used in comparing erosion caused by human activities with that occurring at natural rates (i.e., **geologic erosion**). (*C.F.S.*)

Erosion, accelerated

1. **Erosion** that can be attributed directly or indirectly to the activities of man. (*U.S. Forest Serv.* 1963)

2. **Erosion** much more rapid than **normal erosion**, **natural erosion**, or **geologic erosion**, and occurring primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose bare surfaces (for example, fires). (*Soil Conserv. Soc. Amer.* 1970)

Erosion, bank

Destruction of land area by active cutting of stream-banks. (*Wash. Dep. Ecol.* 1973)

Erosion, beach

The retreat of the shoreline of large lakes and coastal waters caused by wave action, shore currents or causes other than **subsidence**. (*Wash. Dep. Ecol.* 1973)

Erosion, geologic (Natural erosion)

1. The gradual wearing away of the land surface which occurred prior to the occupancy of a land area by man or the present day wearing away which is not due to the activities of man. (*U.S. Forest Serv.* 1963)

2. The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc. (*Soil Conserv. Soc. Amer.* 1970)

Erosion, gully

1. The removal of soil by the formation of relatively large channels or gullies cut into the soil by concentrated surface runoff. In contrast to rills, gullies are too deep to be obliterated by ordinary tillage practices. (*U.S. Soil Conserv. Serv. 1951*)

2. The widening, deepening and headward cutting of small channels and waterways due to erosion. (*Wash. Dep. Ecol. 1973*)

3. The erosion process whereby water accumulates in narrow **ephemeral stream** channels and, over short periods, removes the soil from this narrow area to considerable depths. (*Soil Conserv. Soc. Amer. 1970*)

Erosion, natural (Geologic erosion)

Wearing away of the earth's surface by natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. (*Soil Conserv. Soc. Amer. 1970*)

Erosion, normal

The gradual erosion of land used by man which does not greatly exceed **natural erosion**. (*Soil Conserv. Soc. Amer. 1970*)

Erosion, raindrop. See Erosion, splash.

Erosion, rill

1. The removal of soil by the cutting of numerous small, but conspicuous, water channels or tiny rivulets by concentrated surface runoff.

Rill erosion is intermediate between **sheet erosion** and **gully erosion**. (*U.S. Soil Conserv. Serv. 1951*)

2. The process by which numerous small channels, at the most only several inches deep, are formed on recently cultivated or exposed soils. (*After Soil Conserv. Soc. Amer. 1970*)

Erosion, sheet

1. The removal of a fairly uniform layer of soil from the land surface by runoff water or wind. (*Soil Conserv. Soc. Amer. 1970*)

2. The more or less uniform removal of soil from an area without the development of conspicuous water channels. (*U.S. Soil Conserv. Serv. 1951*)

Erosion, soil

The detachment and movement of soil from the land surface by wind or water. (*Soil Conserv. Soc. Amer. 1970*)

Erosion, splash (Raindrop erosion)

The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff. (*Soil Conserv. Soc. Amer. 1970*)

Erosion, surface

Erosion which removes materials from the surface of the land as distinguished from gully or channel erosion.

The two main types of surface erosion are **sheet erosion** and **rill erosion**. (*U.S. Forest Serv. 1963*)

ES. See Environmental impact statement.

Esthetics. A spelling variation of aesthetics. See Aesthetics.

Estuarine area

U.S. Forest Service usage. The environmental system of an **estuary** and those transitional areas which are consistently influenced or affected by water from an estuary. (*U.S. Forest Serv. 1963, FSM 2605, Sept. 1974*)

Estuarine sanctuary

Coastal Zone Management Act usage. A research area which may include any part or all of an **estuary**, adjoining transitional areas, and adjacent uplands, constituting to the extent feasible a natural unit, set aside to provide scientists and students the opportunity to examine over a period of time the ecological relationships within the area. (*Coastal Zone Manage. Act 1972*)

Estuary

1. U.S. Forest Service usage. All or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connection with the open sea and within which the sea water is measurably diluted with fresh water derived from land runoff, as defined in Public Law 89-753, and similar lands and waters of the Great Lakes, as directed in Public Law 90-454. (*U.S. Forest Serv.* 1963, *FSM* 2605, *Sept* 1974)

2. A water body having an open, natural connection with the sea and within which the sea water is measurably diluted by freshwater runoff. (*C.F.S.*)

3. A body of water in which stream water mixes with and measurably dilutes sea water.

The wide mouth of a river or arm of the sea where the tide meets the river currents, or flows and ebbs. (*Reid* 1961)

4. **Coastal Zone Management Act** usage. That part of a river or stream or other body of water having unimpaired connection with the open sea, where the sea water is measurably diluted with fresh water derived from land drainage. The term includes estuary-type areas of the Great Lakes. (*Coastal Zone Manage. Act* 1972)

Euclidean zoning. See **Zoning, Euclidean.**

Eury- (Euroky-)

A combining prefix denoting ability (of an organism) to tolerate large changes in environmental conditions. For example, eurythermal describes organisms which can tolerate large temperature ranges. (*After Hanson* 1962)

Also see **Steno-**.

Eutrophication

1. The process of overfertilization of a body of water by nutrients that produce more organic matter than the self-purification processes can over-

come. (*Durrenberger* 1973)

2. The term "eutrophic" means well-nourished, and "eutrophication" refers to the natural or artificial addition of nutrients to bodies of water and to the effects of any resulting stimulation of algal growth.

For better understanding a distinction should be made between "eutrophication" in the sense of an increase in nutrient supply as opposed to use in reference to the effects of nutrient enrichment.

When the effects of nutrient enrichment are undesirable, "eutrophication" may be considered to be a form of pollution. (*After Natl. Acad. Sci.* 1969)

Man-caused "eutrophication" is called **cultural eutrophication**.

Evaluation

An examination and judging concerning the worth, quality, significance, amount, degree or condition of something. (*Webster* 1963)

Even-aged management

The actions that will result in a forest, crop, or stand composed of trees having no or relatively small differences in age. (*Ford-Robertson* 1971)

Even-aged stand

A forest **stand** composed of trees having no, or relatively small, differences in age.

By convention the maximum difference admissible is generally 10 to 20 years, though with **rotations** of less than 100 years differences up to 25 percent of the rotation period may be admissible. (*Ford-Robertson* 1971)

EWU. See **Ecological water unit.**

Excepted mineral. See **Mineral, excepted.**

Exception. For the **zoning** terminology usage see **Special exception.**

Exclusive use zoning. See **Zoning, exclusive use.**

Exclusive zoning. See **Zoning, exclusive use.**

Exempt stock

Livestock which are permitted to graze on Federal land free of charge. Usually confined to animals actually used for domestic purposes; saddle horses, milk cows, etc. (*Amer. Soc. Range Manage.* 1964)

Exhaustible resource. See **Nonrenewable resource.**

Existence value (Bequest motive)

The external benefit of natural environments (or any kind of good) that accrues to individuals having no intention of ever visiting the site or using the good in question. These people are willing to give up resources simply to know that the area, feature, or good exists in a particular condition.

The concept of "existence value" has been recognized for some time. John Krutilla (1967) has used the term "bequest motive" to express roughly the same idea. Existence value is preferred because it is less specific in its connotations about motivations; i.e., it does not imply a handing down to later generations.

This type of external benefit is frequently claimed to be associated with wilderness and outstanding natural features. (*Tombaugh* 1971)

Exotic organism

1. More general than exotic species usage. Any organism (plant or animal) that is not native in the area where it occurs. (*Hanson* 1962)

Also see **Naturalized species**, **Feral species**, and contrast with **Resident species**, **Native organism**, and **Endemic organism**.

2. An organism that has been introduced from another continent. (*Soil Conserv. Soc. Amer.* 1970)

Exotic species. See **Exotic organism** and **Species, exotic.**

Expectations

The rules governing social situations, which are specific to particular

societies and even to groups within societies, and which are not consciously thought of, at least until one is not observed.

Expectations are both **normative**, in that they reflect what people believe ought to happen, and **statistical**, in that they express what people believe probably will happen. (*O'Connell* 1974)

Export base analysis (Economic base analysis)

1. A **multiplier** analysis method for estimating regional economic effects of projects. It is particularly suited to rural areas. The economy is divided into two sectors, "export" and "service". The export sector includes all goods and services produced for consumption outside the region being evaluated. The service sector includes all other economic activity. The export sector is assumed to create the need for the service sector, and a multiplier is calculated for each export industry, relating employment in the service sector to the level of activity in that industry. By determining project effects on the export industries, the total economic effects can be estimated. (*After Convery* 1973)

2. A type of economic base analysis. (*E.C.T.*)

Exposure (Slope orientation, Aspect)

The compass direction that the slope of a land surface faces toward (e.g., north, northwest, south). (*After Soil Conserv. Soc. Amer.* 1970)

Extensive recreation. See **Recreation, extensive.**

Externalities. See **Economic externalities.**

Extinct or possibly extinct species. See **Species, extinct or possibly extinct.**

Extractive economics

The economics of industries which remove **natural resources** and supply them to other industries as raw materi-

als. The economic analysis of these industries is more often complicated by depletion of fixed stocks, resource ownership ambiguities, and "common pool" externalities than is true with other types of industries. (*E.C.T.*)

Extraordinary planning

Any type of planning process which, by design, changes existing institutions to obtain alternative desired futures. (*H.J.V.*)

Extrinsic resource

1. Philip H. Lewis usage. Recrea-

tional values created by man-made changes, adaptations, and additions to basic **natural** (i.e., **intrinsic**) resources.

For example the occurrence of mill ponds, historic sites, tourist service facilities, archeological sites, etc. (*Belknap and Furtado 1967*)

2. The term is now used to refer to any resource of human origin—especially in contrast to resources of natural origin (i.e., **intrinsic resources**).

See **Intrinsic resource** for natural recreation resource features.

F

Farmstead or headquarters

Land used primarily for dwellings, barns, pens, corrals, gardens, and other uses in connection with operating farms or ranches. (*U.S. Soil Conserv. Serv. 1970*)

Fault (Earthquake fault)

A ground surface fracture or fracture zone along which there has been displacement of one side with respect to the other. (*Soil Conserv. Soc. Amer. 1970*)

Fault, active

A linear break in the earth's surface that has undergone movement in recent geologic time (the last 10,000 years) and may be subject to future movement. (*After Soil Conserv. Soc. Amer. 1970*)

Fauna

The animal life of an area, "animal" being used in the broad sense to include birds, fish, reptiles, insects, mollusks, crustaceans, etc., in addition to mammals. (*C.F.S.*)

Feasibility (Use feasibility)

A step in G.A. Hills' system for land evaluation. Evaluation of lands use-ability under present and forecasted socioeconomic conditions.

Evaluation based on the present likelihood or under specific management conditions.

The relative advantage of managing or improving a unit considering its **capability** and **suitability** for a specific use under the existing or projected socioeconomic climate. Use feasibility, for example, could be applied on the basis of **accessibility** or population potential. If one unit is closer to a metropolitan center, it would be more accessible and thus would have a higher feasibility rating. (*Belknap and Furtado 1967*)

Feasibility evaluation. See **Feasibility**.

Feature-dominated landscape. See **Landscape, feature-dominated**.

Federal lands

Usage in the defeated 1973 bill for a National **Land Use Policy and Planning Assistance Act**. All Federal land, no matter how it was acquired and no matter what agency has responsibility for its management, except **reservation and other tribal lands**. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Feed

Any non-injurious edible material having nutrient value; may be harvested **forage**, range or artificial pas-

ture forage, grain, or other processed food for livestock or game animals. (*Amer. Soc. Range Manage.* 1964)

Feedback

Negative feedback is a return input which reduces the quantity or quality of outputs, and positive feedback is returned input which increases subsequent outputs. (*After Webster* 1963)

Feedback loop

The pathway by which a portion of the output of a system or process returns to become a part of its inputs. (*After Webster* 1963)

Fee simple ownership. See **Ownership**, fee simple.

Felling (Cutting)

The cutting down of standing trees. "Felling" is not a synonym for logging nor harvesting. These latter terms also include removal of felled trees and some initial processing of the timber prior to removal. (*After Ford-Robertson* 1971)

Felling cycle. See **Cutting cycle**.

Felling rotation. See **Rotation**.

Feral species. See **Species**, feral.

Fertility. See **Soil fertility**.

FES. See **Environmental impact statement**, final, and **Environmental impact statement**.

Filter strip. See **Buffer**, definition 2.

Final cutting

The logging operation which removes the last of the old crop trees in a stand being managed under the shelterwood system of silviculture. (*After Ford-Robertson* 1971)

See **Shelterwood system** for timing of the cuttings in that silvicultural system.

Final environmental impact statement. See **Environmental impact statement**, final.

Final environmental statement. See **Environmental impact statement**, final, and **Environmental impact statement**.

Fire break

A natural or artificial barrier usually created by the removal of vegetation and used to prevent or retard the spread of fire. (*Amer. Soc. Range Manage.* 1964)

Also see **Fuel break**.

Fire planning

Functional planning for the prevention or detection of wildfires or the control of a wildfire. (*E.C.T.*)

Also see **Functional planning**.

Fire, prescribed. See **Prescribed burn**.

Fish

U.S. Forest Service usage. Includes all species of fresh or salt-water fishes, as well as crustaceans, mollusks, and other underwater organisms which are considered part of the fishery resource. (*U.S. Forest Serv., FSM 2605*, Sept. 1974)

Fishery

U.S. Bureau of Land Management usage. Any premises upon which breeding, hatching or fish-rearing facilities are situated when such premises are required to have a license by the state fish and game code, including ponds for commercial use. (*Eisner* 1969)

Flood

1. An overflow or inundation that comes from a river or other body of water and causes or threatens to cause property damage. (*Soil Conserv. Soc. Amer.* 1970)

2. Any relatively high streamflow which overtops the natural or artificial banks in any extended portion of a stream. (*Amer. Geol. Inst.* 1962)

Flood, annual

The highest peak discharge for a stream in a water year. (*Soil Conserv. Soc. Amer.* 1970)

Flood basin

1. The tract actually covered by water during the highest known floods. (*After Amer. Geol. Inst. 1962*)

2. The flat areas between the sloping low plains of the valley sides and the river banks (and commonly containing heavy soils and either no vegetation or a strictly swampy vegetation). (*After Amer. Geol. Inst. 1962*)

Flood frequency

Over a period of years, the average number of times a flood of a given magnitude is likely to occur. (*Amer. Geol. Inst. 1962*)

Flood peak

The maximum volume of flow attained at a given point during a flood event. (*Amer. Geol. Inst. 1962*)

Flood plain

That portion of a stream valley, adjacent to the channel, which is built of sediments during the present regimen (i.e., the state of equilibrium between a stream and its ability to transport sediments) of the stream and which is covered with water when the stream overflows its banks at flood stages. (*Amer. Geol. Inst. 1962*)

The nearly level land situated on either side of a channel which is subject to overflow flooding. (*Soil Conserv. Soc. Amer. 1970*)

The extent of a flood plain obviously fluctuates with the size of overbank stream flows. Thus, no simple, absolute flood plain commonly exists. As a consequence, flood plains are delineated in terms of some specified flood size (e.g., the 50-year flood plain—the area that would be flooded by the largest stream flow that will, on the average, occur once within a 50-year period). Such expected flood-return frequencies are estimated from historic records of stream flows. The largest, absolute flood plain that is ever likely to occur is sometimes referred to as the flood basin. (*C.F.S.*)

Flood plain zoning. See **Zoning, flood plain.**

Flood stage

The water surface elevation above some chosen reference level at which overflow of the natural banks of a stream begins to cause damage in the area in which the depth of the flow is measured. (*After Soil Conserv. Soc. Amer. 1970*)

Flora

1. The plant life of an area. (*Durrenberger 1973*)

2. The sum total of the kinds of plants in an area at one time. (*Hanson 1962*)

Flow duration curve (Duration curve)

A graphical representation of the number of times given stream flow volumes are equalled or exceeded during a certain period of record. (*Soil Conserv. Soc. Amer. 1970*)

Flow resource. See **Renewable resource.**

Fluvial

1. Of or pertaining to streams and flowing waters. (*Soil Conserv. Soc. Amer. 1970*)

2. Growing or living in streams. (*Soil Conserv. Soc. Amer. 1970*)

3. Produced by stream action, as a fluvial plain. (*After Soil Conserv. Soc. Amer. 1970*)

Focal landscape. See **Landscape, focal.**

Folkway

A mode of thinking, feeling or acting common to a people or to a social group—especially a social habit that has not been rationalized or given ethical force. (*Webster 1963*)

Food chain

1. A series of spatially associated species, each of which lives (at least in part) as a predator, parasite or absorber of the next lower down in the series.

This concept is useful for analyzing

the feeding relations between associated animals. (*Carpenter 1938*)

2. The transfer of food energy from the initial source in plants through a series of organisms by repeated eating and being eaten.

“Food chains” are not isolated sequences but are interconnected with one another. The interlocking pattern is often spoken of as the **food web**. (*Odum 1953*)

Food web (Food cycle, Web of life)

1. The more or less complex feeding relationships between all the species occurring in a **biotic community**, showing where each species obtains its food and what other organisms in turn derive their food from it. (*Carpenter 1938*)

A “food web” typically shows all the **food chains** and interconnections between food chains in a biotic community.

2. The total complex pattern of feeding relations of an independent, self-maintaining, major, biotic community. (*Allee 1949*)

Forage

All **browse** and nonwoody plants that are available to livestock or game animals and used for **grazing** or harvested for feeding. (*After Soil Conserv. Soc. Amer. 1970*)

Forage acre

Grazing measurement term. Theoretically, an acre with a complete areal cover of **forage**. A concept used to estimate **grazing capacity**. (*Amer. Soc. Range Manage. 1964*)

Forage acre requirement

The amount of forage, expressed in **forage acres** or fractions thereof, needed to sustain a mature grazing animal for a specified period without injury to the range resource. (*Amer. Soc. Range Manage. 1964*)

Forage, green

Range forage consisting of all avail-

able and **palatable** live plant material and dead tips of growing grasses. (*Amer. Soc. Range Manage. 1964*)

Forage production (Forage yield)

The weight of forage that is produced within a designated period of time on a given area.

The weight may be expressed as either green, air dry or oven dry. The term may also be modified as to time of production such as annual, current year's or seasonal forage production. (*Amer. Soc. Range Manage. 1964*)

Forage, unavailable

That which cannot be grazed by livestock. (*Amer. Soc. Range Manage. 1964*)

Forage yield. See **Forage production**.

Forb

1. Any herbaceous plant other than those in the Gramineae (true grasses), Cyperaceae (sedges) and Juncaceae (rushes) families—i.e., any nongrass-like plant having little or no woody material on it. (*After Amer. Soc. Range Manage. 1964*)

2. A **palatable**, broad-leaved, flowering **herb** whose stem, above ground, does not become woody and persistent. (*Grim and Hill 1974*)

Forecast

A prediction of future conditions and occurrences based on the perceived functioning of the system in question. The accuracy of a forecast is highly dependent on a proper understanding of the system. A “forecast” differs in a strict sense from a **projection**, which is also a prediction of future conditions and occurrences, but is based on an extrapolation of past trends. While the distinction may exist, the dividing line between the two terms is imprecise. (*E.C.T.*)

Also see **Projection**.

Foreground

1. That part of a scene, landscape,

etc., which is nearest to the viewer. (*Webster 1963*)

2. The portions of a view between the observer and up to $\frac{1}{4}$ or $\frac{1}{2}$ mile distant.

The surface patterns on objects and visual elements are important in the "foreground" portions of views. In the foreground portions of a view, observers are able to relate themselves to the size of individual visual elements (such as a tree) and are able to begin to sense their scale relationship to the landscape. Aerial perspective is absent or insignificant in the "foreground", and the intensity and lightness or darkness of colors are seen in maximum contrast. Wind motion in trees or on grass can be seen in this close-in area but seldom beyond. (*Litton 1968*)

Also see **Background and Middle-ground**.

Forest

1. Generally, an ecosystem characterized by a more or less dense and extensive tree cover.

More particularly, a **plant community** predominantly of trees and other woody vegetation, growing more or less closely together. (*Ford-Robertson 1971*)

2. An area managed for the production of timber and other forest produce, or maintained under woody vegetation for such indirect benefits as protection of catchment areas (**watersheds**) or recreation. (*Ford-Robertson 1971*)

3. A common usage reduction of the term "National Forest". The area within the administrative boundaries of a National Forest, irrespective of ground conditions or cover. (*E.C.T.*)

Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93-378); (88 Stat. 476-480) (Humphrey-Rarick Act, Resources Planning Act, RPA)

In recognition of the vital impor-

tance of America's **renewable resources** of the forest, range, and other associated lands to the Nation's social and economic well-being, and of the necessity for a long term perspective in **planning** and undertaking related National renewable resource programs administered by the Forest Service, the Secretary of Agriculture shall prepare a "renewable resource assessment"; shall prepare and transmit to the President a recommended "renewable resource program"; shall develop and maintain on a continuing basis a comprehensive and appropriately detailed inventory of all **National Forest System** lands and renewable resources; and shall develop, maintain, and, as appropriate, revise land and resource management plans for units of the National Forest System, coordinated with the land and resource management planning processes of state and local governments and other Federal agencies. In addition the Secretary of Agriculture may utilize the assessment, resource surveys, and program prepared pursuant to this act to assist states and other organizations in proposing the planning for the protection, use, and management of renewable resources on non-Federal land.

The assessment shall include but not be limited to—(1) an analysis of present and anticipated uses, **demand** for, and **supply** of the renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends; (2) an inventory, based on information developed by the Forest Service and other Federal agencies, of present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible goods and services, together with estimates of investment cost and direct and indirect returns to the Federal government; (3) a description of

Forest Service programs and responsibilities in research, cooperative programs and management of the National Forest System, their interrelationships, and the relationship of these programs and responsibilities to public and private activities; and (4) a discussion of important policy considerations, laws, regulations, and other factors expected to influence and affect significantly the use, ownership, and management of forest, range, and other associated lands.

The program transmitted to the President may include alternatives, and shall provide in appropriate detail for protection, management, and development of the National Forest System, including forest development roads and trails; for cooperative forest service programs; and for research. The program shall be developed in accordance with principles set forth in the **Multiple-Use Sustained-Yield Act** of June 12, 1960, and the **National Environmental Policy Act** of 1969.

In the development and maintenance of land management plans for use on units of the National Forest System, the Secretary shall use a systematic **interdisciplinary approach** to achieve integrated consideration of physical, biological, economic, and other sciences. (*Forest and Rangeland Renewable Resources Planning Act of 1974*)

Forest coordinating requirements. See **Coordinating requirements.**

Forest cover type. See **Cover type.**

Forest land

1. Land at least 10 percent occupied by forest trees of any size or formerly having had such tree cover and not currently developed for nonforest use. (*U.S. Forest Serv. 1972C*)

2. Lands that are at least 10 percent stocked by trees capable of producing timber or other wood products or that exert an influence on the cli-

mate or water regime. (*Anderson, et al. 1972 and U.S. Dep. Agric. 1967*)

3. Land formerly at least 10 percent stocked by forest trees of any size and not currently developed for other uses. (*U.S. Dep. Agric. 1967*)

Forest land use plan (National Forest land use plan)

U.S. Forest Service usage. A plan which gathers and coordinates the direction to be followed in the overall management of a National Forest. Included in the Forest land use plan are applicable national and regional management direction. **Planning area guides**, and **management zone descriptions** (optional), **Forest coordinating requirements**, **basic assumptions**, the Forest situation statement, planning unit identification and priority for study determination, unit plans and maps, and other necessary graphics. Regional Foresters may prescribe additional items to be included. (*U.S. Forest Serv., FSM 8224, Oct., 1973*)

Forest plan. See **Forest land use plan.**

Forest type

A descriptive term used to group **stands** of similar character of development and species composition (due to given ecological factors) by which they may be differentiated from other groups of stands. (*Soc. Amer. For. 1950*)

Also see **Cover type** for actual units of "forest types."

Forest use zoning. See **Zoning, forest.**

Forest zoning. See **Zoning, forest.**

Fragile lands

Those land or water areas containing **ecosystems**, possibly but not necessarily rare, that are sensitive to external stimuli which may disturb their balance, especially in an irreversible direction. (*A.W.M.*)

Fragile or historic lands

Usage in the defeated 1973 bill for

a National Land Use Policy and Planning Assistance Act.

Areas where uncontrolled or incompatible development could result in irreversible damage to important historic, cultural, scientific, or esthetic values or natural systems which are of more than local significance. These lands include shorelands of rivers, lakes, and streams; rare or valuable ecosystems and geological formations; significant wildlife habitats; and unique scenic or historic areas.

Coastal areas are specifically deleted from this definition. In an amendment to this act relating to the Coastal Zone Management Act, the words "coastal wetlands, marshes and other lands inundated by the tides, beaches, dunes and significant estuaries" were deleted from the definition of **fragile or historic lands**. A state is free to add these areas to its state land use program. However, the state need not do so, but rather can keep such areas separate and accountable only to the requirements of the Coastal Zone Management Act. (*U.S. Congr., Senate, Com. Inter., Insular Aff. 1973.*)

This is one of the three types of **areas of critical environmental concern** specifically set forth in this bill. The others are **renewable resource lands** and **natural hazard lands**.

Fragility (Environmental fragility)

1. The quality or state of being: (A) Easily broken or destroyed (B) Unusually susceptible to ill health or harm (C) Barely able or unable to endure without harm the normal day-to-day physical demands of existence. (*After Webster 1963*)

2. In a land use planning context the relative ability of resources to tolerate sustained use without degradation of the resource base (i.e., lowering productivity or desirable resource quality) is sometimes rated on a qualitative scale extending from "fragile"

to "durable." "Fragility" in this usage applies to those resource types or locations which are more or less susceptible to degradation under the presence of whatever use categories have been considered in the evaluation process.

For example, areas of vegetation-covered sand dunes may be characterized as being "environmentally fragile" for off-road vehicle uses, whereas beaches or unvegetated dunes may be said to be "environmentally durable" for the same uses. (*C.F.S.*)

Framework studies and assessments (Type I plan, Level A plan)

U.S. Water Resources Council usage. One of the "levels of planning" for water and related land resources planning by Federal agencies whose activities involve planning and development of water resources as contained in the **Principles and Standards** of the Water Resources Council.

"Framework studies and assessments" will evaluate or appraise on a broad basis the needs and desires of interested people for the conservation, development, and utilization of water and land resources; will identify regions or basins with complex problems which require more detailed investigations and analyses; and may recommend specific implementation plans and programs in areas not requiring further study. They will consider Federal, state, and local means of implementation.

"Framework studies and assessments" are designed to: (1) determine the extent of water and land resource problems and needs; (2) indicate approaches appropriate for their solutions; and (3) when applicable, identify specific areas where regional, river basin, or implementation studies are needed. (*U.S. Dep. of Agric. 1974*)

Free range

Range open to grazing regardless of

ownership and without payment of fees; not to be confused with **open range**. (*Amer. Soc. Range Manage.* 1964)

rost heave

The pushing up of a surface by the accumulation of ice in the underlying soil. (*Soil Conserv. Soc. Amer.* 1970)

fuel break

A wide strip with a low amount of fuel in a brush or wooded area to serve as a line of fire defense and usually covered with grass to provide soil cover. It may contain a **fire break** in the center. (*Amer. Soc. Range Manage.* 1964)

Also see **Fire break**.

ull use

Range management usage. The maximum use that can be made of a range during a **grazing season** without inducing a downward trend in **range condition**. (*Amer. Soc. Range Manage.* 1964)

unctional plan. See **Functional planning**.

unctional planning (Activity planning, System planning)

1. Establishing the specific management actions to be taken in the management of a single resource or activity. Preferably this is undertaken only to detail the implementation of a more general plan involving multiple resources and activities. (*E.C.T.*)

2. Planning which focuses on a particular aspect of the total problem such as production scheduling, or highways or forest conservation in civil governmental planning. (*Branch* 1961)

3. Functional plans—documents prepared for separate resources or activities that identify those separate resource or activity management actions that are necessary to implement the coordinated land management di-

rection established in the National **Forest land use plans**. Examples include timber management plans, transportation plans, land ownership adjustment plans. (*U.S. Forest Serv. FSM* 8213, Oct., 1973)

4. Functional plan—a plan for one element or closely related elements of a **comprehensive plan**, e.g., transportation, sewer and water, recreation, open spaces, etc. prepared by units of government.

Such functional plans of necessity should be closely related to the land-use plan. Plans that do not consider all elements of a comprehensive plan may be considered as functional plans. Functional plans are sometimes referred to as comprehensive for the particular element involved, such as a “comprehensive sewer and water plan” or a “comprehensive open space plan.” (*U.S. Soil Conserv. Serv.* 1970)

Futures

1. Unlike a **scenario** which is constructed for examining specific causal relationships or to aid in making a specific decision, in planning a “future” is an all-inclusive description of what it is believed the planning region will be like if a possible plan or course of action is followed. (*E.C.T.*)

2. The intent here is not to predict the future, but to try to understand where the existing trends will lead if they continue. Once the trends are understood, it is possible to use them to move in a number of desired directions, as in the analogy to the sail boat and wind. In order to create a vision of the future of a region it is necessary to understand the forces that are working on that present system. To fail to understand these trends is to fail to understand the options that are open to the region. (*After Poirier and Vitt* 1974)

G

Game. See *Species, game*.

Game species. See *Species, game*.

Game theory

The study of decision problems in competitive situations. Game theory is concerned with the derivation of rules for making decisions when two or more persons or organizations are competing for some objective. (*U.S. Forest Serv., 1972B*)

General assumption. See *Assumption*.

Generalized soil map. See *Soil map, general*.

General plan. For city planning usage see *Comprehensive plan, definition 1*.

General purpose local government

Usage in the defeated 1973 bill for a National **Land Use Policy and Planning Assistance Act**. Any general purpose unit of local government as defined by the bureau of census and any regional, inter-governmental, or other public entity which is deemed by a governor to have authority to conduct land use planning on a general rather than a strictly functional basis. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

General soil map. See *Soil map, general*.

General soil survey. See *Soil survey and Soil map, general*.

General systems theory

A set of logical deductions about the behavior of a class of objects called systems. General systems theory has been developed in order to explain and explore the general behavior that is common to all of the various empirical systems found within the different disciplines. It is interdisciplinary in nature and finds a place between the level of complete generalization of mathematics and the level of specific relations within each academic field. (*Williams 1971*)

General welfare

1. The state of well-being (i.e., health, happiness, prosperity, etc.) of all persons in a society. (*After Webster 1963*)

2. The sum of the individual utilities in a society. (*After Webster 1963*)

Geographic specific

This term is typically used in land use planning to apply to actions, consequences, or evaluations considered to be valid only for a specified portion of the earth's surface. In other words, one cannot, with validity or without detailed documentation of the similarity between areas, transfer the observations connected with that particular location to others.

"Geographic specific" is used to describe relatively large blocks of land without reference to ownership while **site specific** is used to describe a specific parcel of land. (*C.F.S.*)

Geological area

U.S. Forest Service usage. A unit of land which has been designated by the Forest Service as containing outstanding formations or unique geologic features of the earth's development, including caves and fossils. (*U.S. Forest Serv., FSM 2362.43, July, 1973*)

Areas of this type and all other **Special interest areas** are identified and formally classified primarily because of their recreational values. Areas with similar types of values of scientific importance are formally classified as "Research Natural Areas" (see **Natural Area, Research**). (*W.W.*)

Geologic erosion. See *Erosion, geologic*.

Geologic materials

Any of the naturally occurring mineral or rock substances.

Especially used with reference to classes of such substances whose properties are so significantly different that

a knowledge of their distribution is important in land use planning decisions. (C.F.S.)

geomorphic processes

The physical and chemical means which cause a modification of the earth's surficial form—e.g., volcanic activity, weathering, **mass-wasting**, **erosion**, sedimentation, glacial action, running water, etc. (Thornbury 1969)

geomorphic province. See **Region**, **physiographic**.

geomorphology

The science that deals with land and submarine relief features of the earth's surface and seeks a genetic interpretation of them using the principles of physiography (see **physiographic**) in its descriptive aspects and of dynamic and structural geology in its explanatory phases. (Webster 1963)

Goal (Plan goals, Management goal)

1. A concise statement of an organization's central strategy in addressing a problem expressed in terms of a desired state or process that operating **programs** are designed to achieve.

A goal is normally expressed as a broad, general statement, is usually not quantifiable, and is timeless in that it usually has no specific date by which it is to be completed. Often, it would not be expected that a "goal" could ever be completely achieved. The "goal" is the principal statement from which **objectives** must be developed.

For example, U.S. Department of Agriculture goals relating to their **mission** to work on problems associated with agricultural production are (1) to work for disease and pest control and (2) to conduct research on production. (U.S.D.A. Off. Manage. and Finance 1974)

2. Characteristically, "goals" are enduring statements of purpose, often not attainable in the short term, and frequently incapable of expression in

quantifiable terms. (U.S. Forest Serv. 1972B)

3. The broad end toward which effort is directed. In the context of land use planning, goals are normally stated in terms of the fulfillment of broad public needs, the preservation of fundamental constitutional principles, the achievement of targeted levels of excellence, the alleviation of major problems, or other justifiable **missions** or purposes to be served by government effort. (U.S. Forest Serv. 1972B)

4. A goal is societal consensus of that which is good for the constituency at some level of generalization—the particular level being determined by the **planning level** (such as state, metropolitan region, city). (After Hills, Love and Lacate 1970)

Goal programming

A mathematical approach to optimization. A series of goals are established which can be expressed as mathematical equations. However, due to constraints on the original problem, not all the goals can be met simultaneously. It is necessary to allow positive and negative slack within these goals equations. This slack is allocated to "slack variables," which are combined with the goals to form a linear equation to be minimized or maximized and a series of accompanying constraint equations. This system of equations is then solved by standard **linear programming techniques**. (After Goodman 1974)

Graphic scale

A bar, or other such graphic device, on a **scale** drawing, divided into properly scaled-down measurement units—such as 100, 500, 1000, 5000 yards or 0.25, 0.5, 1.0, 5.0 miles. In subsequent photographic reduction or enlargement of a drawing, the "graphic scale" becomes a device from which distances can be readily and accurately measured. (C.F.S.)

Grazing

Consumption of range or artificial pasture forage by animals. (*Amer. Soc. Range Manage.* 1964)

For the different types of grazing practices see **Grazing, continuous**; **Grazing, deferred**; **Grazing, deferred rotation**; **Grazing, heavy**; **Grazing, intermittent**; **Grazing, light**; **Grazing, moderate**; **Grazing, premature**; **Use, proper**; **Grazing, rest-rotation**; **Grazing, rotation**; and **Grazing, spot**.

Grazing, alternate. See **Grazing, rotation**.

Grazing capacity

The maximum stocking rate possible without inducing damage to vegetation or related resources. (*Amer. Soc. Range Manage.* 1964)

Also see **Carrying capacity, range**.

Grazing capacity, maximum

The maximum number of animals that a given range area is capable of supporting without injury to soil, vegetation or watershed. (*Amer. Soc. Range Manage.* 1964)

Grazing, continuous

Allowing domestic livestock to graze a specific area throughout the grazing season.

The term is not necessarily synonymous with grazing for a 12-month period or a calendar year. (*Amer. Soc. Range Manage.* 1964)

Grazing, continuous use. See **Grazing, continuous**.

Grazing, deferred

Discontinuance of grazing by livestock on an area for a specified period of time during the growing season to promote plant reproduction, establishment of new plants, or restoration of vigor by old plants. (*Amer. Soc. Range Manage.* 1964)

Grazing, deferred rotation

Discontinuance of grazing on various parts of a range in succeeding years, allowing each part to rest suc-

cessively during the growing season to permit seed production, establishment of seedlings, or restoration of plant vigor.

Two, but usually three or more, separate grazing units are required. Control is usually insured by unit fencing, but may be obtained by herding on sheep ranges. (*After Amer. Soc. Range Manage.* 1964)

Grazing district

1. An administrative unit of Federal range established by the Secretary of Interior under the provisions of the Taylor Grazing Act of 1934, as amended. (*Amer. Soc. Range Manage.* 1964)

2. An administrative unit of state, private, or other rangelands, established under certain state laws. (*Amer. Soc. Range Manage.* 1964)

Grazing, heavy

A comparative term (often used in research but may apply to practical management as well) which indicates that the stocking rate of a pasture is relatively greater than other pastures. Often erroneously used to mean overuse. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing, moderate** and **Grazing, light**.

Grazing, intermittent

Grazing range or artificial pasture for indefinite periods at indefinite intervals. (*Amer. Soc. Range Manage.* 1964)

Grazing land, native

Grazing land used primarily for production of native forage plants maintained or manipulated primarily through grazing management. Native grazing lands include **rangeland**, **grazeable woodland**, and **native pasture** individually or collectively. (*D.E.H. and B.W.*)

Also see **Rangeland** and **Pasture, native**.

Grazing, light

A comparative term (often used in research but may apply to practical management as well) which indicates that the **stocking rate** of one pasture is relatively less than that of other pastures.

Often erroneously used to mean "underuse" of **grazing capacity**. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing, heavy** and **grazing, moderate**.

Grazing management plan

A program of action designed to secure the best practicable use of range. (*Amer. Soc. Range Manage.* 1964)

Grazing, moderate

A comparative term (often used in research but may apply to practical management as well) which indicates that the **stocking rate** of a pasture is in between the rates of other pastures.

Often erroneously used to mean **proper use**. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing, heavy** and **Grazing, light**.

Grazing permit (Grazing license)

Official, written permission to graze a specified number, kind and class of livestock for a specific period on a defined **range allotment**. (*Amer. Soc. Range Manage.* 1964)

Grazing preference (Preference)

1. Selection of certain plants over others by grazing animals. (*Amer. Soc. Range Manage.* 1964)

2. In the administration of public lands, the basis upon which permits and licenses are issued for grazing use. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing privilege** and **Grazing right**.

Grazing, premature

1. Grazing before **range readiness**. (*Amer. Soc. Range Manage.* 1964)

2. Grazing before range plants have reached sufficient seasonal develop-

ment to avoid over-use or before the soil has become firm enough to withstand or before the plant community is ready to withstand the presence of grazing animals.

The stage of **range readiness** is reached when these conditions are met and range utilization may properly begin. (*Ford-Robertson* 1971)

Grazing pressure

The actual animal-to-forage ratio at a specific time.

For example, three **animal units** per ton of standing forage. (*Amer. Soc. Range Manage.* 1964)

Grazing privilege

Permissive use of lands for grazing by livestock. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing right** and **Grazing preference**, definition 2.

Grazing, proper. For range management usage see **Use, proper**.

Grazing rate. See **Stocking rate**.

Grazing, rest-rotation

An intensive system of management whereby grazing is deferred on various parts of the range during succeeding years, allowing the deferred part complete rest for one year.

Two or more units are required. Control by fencing is usually necessary on cattle range, but may be obtained by herding on sheep ranges. (*Amer. Soc. Range Manage.* 1964)

Grazing right

A right to graze public lands, permanently vested in the beneficiary as specified by the terms of the law or contract. (*Amer. Soc. Range Manage.* 1964)

Also see **Grazing preference** definition 2 and **Grazing privilege**.

Grazing, rotation

Grazing two or more **pastures** or parts of a **range** in regular order, with definite recovery periods between

grazing periods. Where only two fields are involved, sometimes called alternate grazing.

Contrasts with **continuous grazing**. (*Soil Conserv. Soc. Amer.* 1970)

Also see **Planned grazing system**.

Grazing season

1. A period of grazing to obtain optimum use of the **forage** resource.

2. On public lands—An established period for which **grazing permits** are issued. (*Amer. Soc. Range Manage.* 1964)

Grazing, selective

The grazing of certain plant species on the range to the exclusion of others. (*Amer. Soc. Range Manage.* 1964)

Grazing, spot

Repeated grazing of small areas while adjacent areas are lightly grazed or unused. (*Amer. Soc. Range Manage.* 1964)

Grazing system

The manipulation of livestock grazing to accomplish a desired result. (*Amer. Soc. Range Manage.* 1964)

Grazing trespass

The grazing of livestock on a range area without proper authority. (*Amer. Soc. Range Manage.* 1964)

Grazing unit

An area of rangeland, public or private, which is grazed as an entity. (*Amer. Soc. Range Manage.* 1964)

Great soil group. See **Soil great group**.

Green belt

1. Areas around villages, towns or cities in which development is strictly controlled and usually not permitted at all. A useful device for preventing the endless sprawl of towns or the coagulation of one town with another, providing townspeople with a welcome release from the strain of city life, and protecting the special character of some towns. The main deficiency of

green belt preservation is that it encourages the leap-frogging of development over the green belt to the land beyond it. (*Ashworth* 1973)

2. "Green belts" are a particular type of **open space**.

Green forage. See **Forage, green**.

Gross residential density. See **Residential density**.

Ground-lead logging. See **Logging, ground-lead**.

Groundwater

Water within the earth that supplies wells and springs. Specifically, water in the zone of saturation where all openings in soils and rocks are filled—the upper surface of which forms the water table. (*After Webster* 1963)

Groundwater recharge area. See **Groundwater and Recharge**.

Groundwater table. See **Water table**.

Group. See **Social group**.

Group culture. See **Subculture**.

Group cutting

1. U.S. Forest Service usage. A **clearcutting system** variation in which the logging operation removes all merchantable timber from an area smaller than that normally recognized in timber type and condition class mapping.

Group cuts should not exceed ten acres, nor usually be less than one-fifth acre. (*U.S. Forest Serv., FSM 2471 R-3, date unknown*)

Group cuts normally will not exceed 25 acres in size nor rarely less than 5 acres in size. (*U.S. Forest Serv., FSM 2471.21 R-5, Sept. 1971*)

2. U.S. Forest Service usage of group, patch, strip, and stand cutting. These are essentially size designations of the same logging approach—commonly known as clearcutting. All require the removal of all merchantable trees except a few which may

sometimes be carried over where needed for other forest values such as nesting sites, food caches, etc.

"Group cuts" are on areas which are smaller than the size normally recognized in type and condition class mapping. These should not exceed 10 acres, nor usually be less than one-fifth acre.

Patch cuts are on areas which are of a size generally mapped for type and condition and for control, but which do not include the entire stand of which they are a part.

Strip cuts are on areas running through a stand and usually of a width equal to one to two times the general stand height.

Stand cuts are on areas large enough to be practical for management. (*U.S. Forest Serv., FSM 2471.21, June, 1973*)

Guide. See **Planning area guide.**

Guideline

U.S. Forest Service usage. A steering or usual course of action, but not mandatory nor requiring a superior's approval for deviation from it. (*U.S. Forest Serv. 1972B*)

Gully

A channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains or during the melting of snow. The distinction between "gully" and **rill** is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage. (*Soil Conserv. Soc. Amer. 1970*)

Gully erosion. See **Erosion gully.**

H

Habitat

1. The natural environment of a plant or animal. (*Durrenberger 1973*)

2. The natural place of abode of a plant or other organism. The locality where the organism may generally be found, and where all essentials for its development and existence are present. A geographical **niche**. Habitats are described by their geographical boundaries, or with such terms as "shady woodlands", "banks of streams", "dry hillsides", etc. (*Stamp 1961*)

3. From the point of view of plant ecology a "habitat" may be described as the place of abode of a plant, a **plant community** or in some cases even a group or a **succession** or related plant communities, together with all factors operative within the abode, but external to the plants themselves. This is said to correspond more or less closely to **environment**. (*March 1964, citing Yapp 1922*)

4. The type of locality and immediate environment in which an organism grows. (*After Lawrence 1955*)

Also see **Environment**.

Hardpan

A hardened soil layer in the lower A or in the B **horizon** caused by cementation of soil particles with organic matter or with materials such as silica or calcium carbonate.

The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not disintegrate in water. (*Soil Conserv. Soc. Amer. 1970*)

Hard pesticides. See **Persistent pesticides.**

Harvesting

A loose term for the removal of produce (i.e., a merchantable material) from the forest for utilization; comprising therefore **cutting**, sometimes further initial processing (e.g., with trees, topping and trimming) and extraction (removal from the forest).

When "harvesting" timber, "harvesting" is a rough or quasi-synonym with **logging**. (*Ford-Robertson 1971*)

In imprecise usage **logging**, **harvesting**, and **silviculture** are used seemingly interchangeably by different people, often with vehemence as to which is the correct term in a given situation. According to Ford-Robertson (1971) "silviculture" has as its primary concern the establishing, growing, and tending of forests. "Harvesting" and "logging", however, deal specifically with the extraction of resources from the forest. "Logging" is restricted to the cutting and extraction of timber (wood other than fuel wood after **primary conversion**) and "harvesting" expands this to include the cutting, initial processing if any, and extraction of any forest product. (*After Ford-Robertson 1971*)

Hayland

1. U.S. Soil Conservation Service usage. Land used primarily for the production of hay from longterm stands of adapted forage plants. (*U.S. Soil Conserv. Serv. 1970*)

2. Land permanently used for forage, such as land on which the stand is improved occasionally by preparing a seedbed or applying other measures. (*U.S. Dep. Agric. 1967*)

3. Land from which grasses and legumes are harvested for hay or seed and which is then pastured or left to grow forage. (*U.S. Dep. Agric. 1967*)

4. Land in wild hay. (*U.S. Dep. Agric. 1967*)

5. Land in mountain meadows. (*U.S. Dep. Agric. 1967*)

Hazard

1. A possible source of peril, danger, duress, or difficulty. (*Webster 1963*)

2. A condition which tends to create or increase the possibility of loss. (*Webster 1963*)

Heat island

1. An area with air temperatures measurably greater than that of its surroundings. Urban areas form "heat islands". (*Durrenberger 1973*)

2. "Heat island effect". An air circulation phenomenon generally found in cities. Warm air tends to concentrate in the city's center, probably because of the mass of tall buildings and concentration of paved surface. This warm air rises, carrying with it its burden of pollution. As the polluted air moves up over the city, spreads out, cools, and sinks at the city's periphery, it forms a distinctive ceiling (composed of suspended pollutants) known as a haze hood or dome. Cooler air from the edge of the city flows into the center to replace the rising air and is followed again by cool air from the city's edge. Thus, a self-contained circulatory system is set up that is altered only by a strong wind capable of breaking up the pollution-formed ceiling. Such a heat island, if it becomes stabilized for a sufficient length of time, can create hazardous concentrations of pollutants. (*Sesco, et al. 1973*)

Heavy grazing. See **Grazing, heavy**.

Heavy metals

Metals having a specific gravity (i.e., weight in comparison to weight of an equal volume of water) of 5.0 or over, and generally toxic in relatively low concentrations to plant and animal life. Such metals can persist in animal tissue and are capable of increasing in concentration as they pass upward through the **food chain**. Major sources of heavy metal contamination are pesticides, limestone and phosphate fertilizers, manures and sewage sludges, and mine wastes. Examples include lead, mercury, cadmium, and arsenic. (*Sesco, et al. 1973*)

Hedging

Range management usage. A term

used to describe the appearance of **browse** plants that have been browsed so as to appear artificially clipped.

The consistent browsing of terminal buds of browse species causes excessive lateral branching and a reduction in upward growth. (*Amer. Soc. Range Manage.* 1964)

Herb

Any flowering plant except those developing persistent woody stems above ground. (*Amer. Soc. Range Manage.* 1964)

Herbage

Herbs taken collectively, usually used in the same sense as **forage**, except that it may include material not acceptable to grazing or browsing animals. (*Amer. Soc. Range Manage.* 1964)

Herbicide (Weedicide)

A substance used to inhibit or destroy plant growth. If its effectiveness is restricted to a specific plant or type of plant, it is known as a selective herbicide. If its effectiveness covers a broad range of plants, it is considered to be a non-selective herbicide. (*Sesco, et al.* 1973)

Herbivore

An animal that feeds on plant substances. (*Durrenberger* 1973)

Heterogeneous

Differing in kind; having qualities which are significantly not uniform throughout; possessed of different characteristics; opposed to **homogeneous**. (*After Soil Conserv. Soc. Amer.* 1970)

Heterotrophic organism

An organism that is dependent on organic matter for food. (*Geckler, et al.* 1963)

In contrast, an **autotrophic organism** is capable of using inorganic substances as its source of food. (*After Geckler, et al.* 1963)

Hierarchical

1. Of, relating to or constituting a sequentially related series of levels in a classification scheme. (*After Webster* 1963)

2. A type of classification technique whose successively lower (i.e., more specific) level units must fit entirely within the separate units delineated by the next higher (i.e., less specific) level in that system. The boundaries of the more specific level units must occur within or coincide with (and not cross) those boundaries delineated for the units of the next less specific level in the classification system. (*C.F.S.*)

Highwall

The unexcavated face of exposed **overburden** and coal or ore in an **open-pit mine** or the face or bank on the uphill side of a **contour strip mine** excavation. (*Thrush* 1968)

High-lead logging. See **Logging, high-lead.**

Historical area

U.S. Forest Service usage. Sites and areas which have been designated by the Forest Service as containing important evidence and remains of the life and activities of early settlers and others who used or visited the area or the sites where important events took place. Examples are battlegrounds, remnants of mining camps, old cemeteries, important pioneer roads and trails, and early trading sites. (*U.S. Forest Serv., FSM 2361.22, July 1973*)

Areas of this type and all other **special interest areas** are identified and formally classified primarily because of their recreational values. (*W.W.*)

Historic and cultural sites

These sites are associated with the history, tradition or cultural heritage of national, state or local interest and are of enough significance to merit preservation or restoration.

The location of the feature establishes the site. Recreational activities on these sites center around sight-seeing, enjoyment and study of the historic or cultural feature. Management is generally limited to activities that would effect such preservation and restoration as may be necessary to protect the features from deterioration and to interpret their significance to the public. Administration is by all levels of public agencies and private land-owners who identify, set aside and manage historic and cultural areas. (Eisner 1969)

Historic preservation

National Historic Preservation Act of 1966 usage. The protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures and objects significant in American history, architecture, archeology or culture. (*U.S. Forest Serv., FSM 2361.01, Feb. 1974*)

Historic Sites Act (49 Stat. 666)

The Historic Sites Act of 1935 authorizes the programs that are known as the Historic American Buildings Survey, the Historic American Engineering Record, and the National Survey of Historic Sites and Buildings; authorizes the establishment of National Historic Sites and otherwise authorizes the preservation of properties "of national historical or archeological significance"; authorizes the designation of **National Historic Landmarks**; establishes criminal sanctions for violation of regulations pursuant to the act; authorizes interagency, intergovernmental, and interdisciplinary efforts for the preservation of cultural resources; and other provisions.

The program is administered by the U.S. National Park Service. (*U.S. Forest Serv., FSM 2361.01, Feb. 1973*)

Holding capacity. See **Carrying capacity.**

Holistic

1. Emphasizing the organic or functional relation between parts and whole. (*After Webster 1963*)

2. In accordance with the theory or doctrine according to which a whole cannot be expressed as the simple sum of its parts. (*After Webster 1963*)

Homeostasis

One of the most important features of a **biotic community** is that it possesses mechanisms for self-regulation. All communities, except possibly the very simplest types, contain within themselves regulatory mechanisms which enable them constantly to adjust themselves to the changing conditions of their physical environments. This ability for self-regulation is called "homeostasis." (*Dice 1952*)

Homogeneous

Of the same kind or nature; consisting of similar parts or of elements of a like nature; having qualities which are significantly uniform throughout; opposed to **heterogeneous**. (*After Soil Conserv. Soc. Amer. 1970*)

Homogeneous response unit (Response unit)

A particular land (or water) unit which is delineated on the assumption that it is sufficiently uniform within its boundaries to respond in a **homogeneous** manner throughout the area to any set of inputs. That is, any treatment, stimulus, or set of conditions will cause the same reaction, response, or set of outputs when applied to each location within the unit. (*E.C.T.*)

Also see **Ecological land unit**, **Choropleth map** and **Resource capability unit**.

Hot spoils. For mining usage see **Mining debris, hot**.

Human and Community Development System

U.S. Forest Service usage. This sys-

tem is concerned with actions that help people and communities to help themselves. The system includes activities that provide (1) youth development through working and learning experiences, (2) adult employment and training opportunities through various Federal manpower programs, (3) community planning and development information and services for rural areas, and (4) technical forestry assistance for urban areas in the establishment, management, and protection of needed open space and the use of trees and woody shrubs.

One of the six "systems" established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act of 1974**. It has grouped its various programs into these six "systems," each of which incorporates all the activities concerned with developing and managing a specific resource. (*U.S. Forest Serv. 1974A*)

The six "systems" are: **Land and Water, Timber Resource, Outdoor Recreation and Wilderness, Rangeland Grazing, Wildlife and Fish Habitat, and "Human and Community Development"**.

Human community

1. The spatial, or territorial, unit in social organization. (*O'Connell 1974*)

2. "Sense of community". The psychological cohesiveness or feeling of belonging that is associated with spatial or territorial units of social organization. (*O'Connell 1974*)

Social activity marked by a feeling of unity but also by individual participation completely willing and not

forced or coerced and without a loss of individuality. (*Webster 1963*)

Human environment. See **Environment, human**.

Humphrey-Rarick Act. See **Forest and Rangeland Renewable Resources Planning Act of 1974**.

Hydraulic mining. See **Mining, placer**.

Hydric. See **Hygic**.

Hydrograph

A graph showing variation in the water depth in a stream or the volume of water flowing past a point in a stream over a period of time. (*After Soil Conserv. Soc. Amer. 1970*)

Hydrologic cycle (Water cycle)

The circuit of water movement from the atmosphere through various stages or processes on the ground (such as precipitation, interception, runoff, infiltration, percolation, storage) and then back to the atmosphere again by evaporation, and transpiration. (*Soil Conserv. Soc. Amer. 1970*)

Hydrology

A science dealing with the properties, distribution, and circulation of water, specifically the study of water on the surface of land, in the soil and underlying rocks, and in the atmosphere, particularly with respect to evaporation and precipitation. (*After Webster 1963*)

Hydrosere. See **Succession**.

Hygic (Hydric)

1. Refers to a **habitat** characterized by wet or moist conditions rather than **mesic** (moderate) or **xeric** (dry) conditions. (*Hanson 1962*)

2. The nature of an organism adapted to wet conditions. (*Dansereau 1957*)

Ice cream species

Range management usage. An exceptionally **palatable** species sought and grazed first by livestock and game animals.

Such species are usually overutilized under proper grazing. See **Use, over.** (*Amer. Soc. Range Manage.* 1964)

Igneous rock. See **Rock, igneous.**

Implementation plan

A document for giving practical effect to, or ensuring the actual fulfillment of, some regulatory **standard** or goal by specific measures. (*Sesco, et al.* 1973)

Implementation studies (Level C plan)

U.S. Water Resources Council usage. One of the "levels of planning" for water and related land resources planning by Federal agencies whose activities involve planning and development of water resources as contained in the **Principles and Standards** of the Water Resources Council.

Implementation studies are project feasibility studies undertaken by the Department. These studies may be conducted to implement findings, conclusions, and recommendations of **framework and assessment studies**, regional or river basin studies, other Federal-state investigations or at the request of local government organizations. Implementation studies are directed toward carrying out the project installation authorities of Public Law 83-566, Public Law 78-534, and the "Resource Conservation and Development" Program.

Plan formulation for implementation studies will focus on a recommended plan of action to follow within the next 10-15 years. Long-range projections of water and land resource needs will be considered; however, primary attention will be toward a plan

to meet the near-term needs and alleviate problems. Plans will be directed toward a set of specific components of the two objectives (national economic development, and environmental quality, see **Principles and Standards**) which will be determined for the planning area. The plan formulation process will be responsive to the identified needs and problems that relate to the water and land resources in the area and the planning functions that may be employed to meet the needs. (*U.S. Dep. of Agric.* 1974)

Imponderable value. See **Intangible value.**

Improvement cutting

1. The elimination or suppression of less valuable trees to increase growth rates of more valuable trees, typically in mixed uneven-aged forest. (*Ford-Robertson* 1971)

2. U.S. Forest Service usage. Cutting made in an immature stand to improve the stand composition by removing trees of poor form and/or poor genetic qualities. (*U.S. Forest Serv., FSM 2471 R-3, date unknown*)

Income distribution effects

Effects of proposed activities on the proportion of the total income of an area received by each segment of the population.

As an example, "the rich get richer and the poor get poorer" is talking about income distribution effects. A doubling of everyone's income, so the shares of the total remain the same, has no income distribution effect. (*E.C.T.*)

Incommensurable values

Resource yields for which no method yet exists for conversion to a common measurement scale or unit (such as dollars) for purposes of comparative evaluation of relative importance. For example, comparison of the aesthetic with the timber yields of land is diffi-

cult because it is often impossible to express the former objectively in dollar values. (*C.F.S.*)

Also see **Intangible value**.

incompatible uses

Land uses which cannot exist together by reason of either competition for limited resources or use by-products which prevent the alternative use. For example, timber harvesting and wilderness preservation are incompatible uses for one piece of land. (*E.C.T.*)

Also see **Conflicting uses**, **Compatible uses**, and **Complementary uses**.

increaser plant species (Increaser)

Range management usage. Plant species of the original vegetation that increase in relative amount, at least for a time, under **overuse**. (*Amer. Soc. Range 1964*)

Also see **Invader plant species** and **Decreaser plant species**.

incrementalism (Muddling through, Disjointed incrementalism, Incremental planning)

An alternative planning approach to **comprehensive planning** based on the assumption that due to practical difficulties true comprehensive planning cannot exist. As an alternative it is suggested planners concentrate on a **recursive** process of choosing among policies based on incremental changes to existing policies without trying to set overall goals and without basing the policies on theoretical predictions of the consequences of the policies or on an understanding of the system being regulated. Instead the planners would rely heavily on the record of past experience with small policy steps to predict the consequences of similar steps extended into the future. (*After Lindblom 1959*)

Neither social scientists, nor politicians, nor public administrators yet know enough about the social world

to avoid repeated error in predicting the consequences of policy moves. A wise policy-maker consequently expects that his policies will achieve only part of what he hopes and at the same time will produce unanticipated consequences he would have preferred to avoid. If he proceeds through a succession of incremental changes, he avoids serious lasting mistakes in several ways. In the first place, past sequences of policy steps have given him knowledge about the probable consequences of further similar steps. Second, he need not attempt big jumps toward his goals that would require predictions beyond his or anyone else's knowledge, because he never expects his policy to be a final resolution of a problem. His decision is only one step, one that if successful can quickly be followed by another. Third, he is in effect able to test his previous predictions as he moves on to each further step. Lastly, he often can remedy a past error fairly quickly—more quickly than if policy proceeded through more distinct steps widely spaced in time. (*Lindblom 1959*)

Because practitioners of this approach expect to achieve their goals only partially, they would expect to repeat endlessly the sequence just described, as conditions and aspirations changed and as accuracy of prediction improved. (*Lindblom 1959*)

Any significant problem for planners or policy makers involves **trade-offs** among conflicting values, and when dealing with incrementally different alternatives this is always a problem of adjustments at a margin. But there is no practicable way to state marginal objectives or values except in terms of particular policies. The only practicable way to disclose one's relevant marginal values even to oneself is to describe the policy one chooses to achieve them. Consequently no overall goal is developed

and means and ends are simultaneously chosen. (*After Lindblom 1959*)

Ideally, rational-comprehensive analysis leaves out nothing important. But it is impossible to take everything important into consideration unless "important" is so narrowly defined that analysis is in fact quite limited. Limits on human intellectual capacities and on available information set definite limits to man's capacity to be comprehensive. In actual fact, therefore, no one can practice the rational-comprehensive method for really complex problems, and every administrator faced with a sufficiently complex problem must find ways drastically to simplify. In the method of successive limited comparison, simplification is systematically achieved in two principal ways. First, it is achieved through limitation of policy comparisons to those policies that differ in relatively small degree from policies presently in effect. Such a limitation immediately reduces the number of alternatives to be investigated and also drastically simplifies the character of the investigation of each. The second method of simplification of analysis is the practice of ignoring important possible consequences of possible policies, as well as the values attached to the neglected consequences. (*Lindblom 1959*)

Almost every interest has its watchdog. Without claiming that every interest has a sufficiently powerful watchdog, it can be argued that our system often can assure a more comprehensive regard for the values of the whole society than any attempt at intellectual comprehensiveness. (*Lindblom 1959*)

Also contrast with **Comprehensive plan**.

Incremental planning. See **Incrementalism**.

Index (Index number)

1. A ratio or some other number

derived from a series of observations which is used as an **indicator** or measure of conditions, properties, phenomena or trends. (*Webster 1963*)

2. A composite numerical value for some environmental component (such as air or water quality) for which we have more than one **indicator**. (*Thomas 1972*)

3. A number used to indicate change in magnitude (as of cost, price or volume of production) of some complex variable as compared with its magnitude at some specified time—usually taken as having an index number of 100. (*Webster 1963*)

Index, economic

1. A measurable aspect of society which indicates the extent to which certain more complex aspects are present. [Examples: the "consumer price index" or "gross national product."] (*Webster 1963*)

2. A figure which discloses the relative change, if any, of prices, costs, or some similar phenomena between one period of time and some other period of time selected as the "base period." The latter period is usually assigned the index number of 100. There are numerous methods of calculating an index number. (*Sloan 1961*)

Index number. See **Index**.

Index species. See **Indicator species**.

Indicative planning

A method of planning (notably used in France) which primarily restricts itself to analyzing the economy and then making this information available to industry. The modern economy requires the employment of large investments whose profitability may be profoundly affected by changes in the environment. These changes not only occur rapidly, they are difficult to predict. The individual business concern has no valid basis for such calculation. The entire economy

is interdependent beyond the analysis capabilities of a single firm. The guiding principle of "indicative planning" is to integrate all the effects of interdependence by, on a nationwide scale, studying the markets and making detailed analyses and forecasts. The instrument used in making these forecasts is the economic **input-output analysis**.

This information is then distributed to the private sector, which is primarily left alone. By providing this complete information it is assumed that industry will adjust its production, use of resources, and investments to satisfy the projected demands, thus avoiding bottlenecks, smoothing business cycles, and increasing harmony and growth. The planning is implemented by "indicating" to all individuals involved the future consequences of their actions, helping individuals to arrive at a common view on the future of a particular economic activity in relation to the national development aims, demonstrating the advantages of conforming to this common view, and only occasionally coercing conformance.

Thus, "indicative planning" is not a planning for land managers, but a planning for managers of societies and economics. (After Masse 1961)

Indicator, biologic (Ecologic indicator)

An organism or a class of organisms (such as a species) or an ecologic community that is so strictly associated with particular environmental conditions that its presence is a fairly certain sign or symptom of the existence of these conditions. (After Webster 1963)

Indicator organism. See **Indicator species**.

Indicator plant. See **Indicator species**.

Indicator species (Index species, Indicator organism)

1. A particular type of plant or ani-

mal whose presence in a certain location or situation is a fairly certain sign or symptom that particular environmental conditions are also present.

For example, the presence of *Escherichia coli* bacteria in water is used to indicate probable pollution by human fecal matter. (C.F.S.)

2. **Index species**—A plant or animal species so highly adapted to a particular kind of environment that its mere presence is sufficient indication that specific conditions are also present. (After Webster 1963)

A living label of the presence of a specific set of conditions. (After Webster 1963)

Biologic indicator can be used to refer to signs or symptoms associated with any level of organic organization while **indicator species** only refers to those associated with the species level. (C.F.S.)

4. Any organism which by its presence or absence, its frequency or its vigor, indicates a particular property of its surrounding environment. For example, a particular plant might indicate a soil type or the presence or absence of an air or water pollutant. (Sesco, et al. 1973)

Indices. See **Index**.

Indifference curve

A graphical delineation of all combinations of two goods or services with which an individual would be equally pleased (indifferent between). (E.C.T.)

Also see **Indifference map**.

Indifference map

A two-dimensional graph of a combination of **indifference curves** denoting an individual's preference system to various combinations of two goods or services. Each line of the family of curves represents equally desirable mixtures of the quantities in question. With different curves representing differing levels of satisfaction it is

possible to determine what quantities an individual will consume when faced with different prices and incomes. (After Sloan 1961)

Indigenous, species. See **Species, indigenous.**

Indirect effect (Secondary effect)

A condition caused by an action or inaction through intermediary causal agents. An effect for which the causal linkages to the action or inaction are not readily apparent. Contrasts with **direct effect**. This is not a measure of importance, but merely a classification by causal linkages. Direct effects are usually easier to detect and measure with certainty, but they may be either more or less important than indirect effects. (E.C.T.)

Individual distance (Personal distance)

1. **Environmental psychology** usage. The normal spacing maintained by non-contact animals. (Worthington 1974, citing Heidiger 1961)

2. Individual distance exists only when two or more members of the same species are present, and is greatly affected by population density and territorial behavior. "Individual distance" and **personal space** interact to affect the distribution of persons. The violation of "individual distance" is the violation of society's expectations. (Sommer 1969)

Induced output. See **Output, induced.**

Inexhaustible resource

"Inexhaustible resource" is a term which should be discouraged, for in the final analysis probably no resource is absolutely inexhaustible, and the term may have an undesirable reaction (or lead to misunderstanding) among the lay public. ((E.M.G.)

Also see **Renewable resource.**

Infiltration

The movement of water into the soil through pores or other openings, connoting flow into a soil in contradis-

tion to the word **percolation** which connotes flow through a soil. *Soil Conserv. Soc. Amer.* 1970)

Infiltration capacity. See **Infiltration rate.**

Infiltration rate (Infiltration capacity)

The maximum rate at which the soil under various specified conditions (including the presence of an already excess amount of water) can absorb falling rain or melting snow. (After *Soil Conserv. Soc. Amer.* 1970)

Information system

A combination of personnel, efforts, forms, formats, instructions, procedures, data, communication facilities and equipment that provides an organized and interconnected means (automated, manual, or a combination of these) for recording, collecting, processing, transmitting and displaying information in support of specific functions. (U.S. Forest Serv. 1972B)

Also see **Computer information system.**

Infrastructure (Social overhead capital)

1. The foundation underlying a nation's, region's, or community's economy (transportation and communications systems, power facilities, schools, hospitals, etc.). (U.S. Forest Serv. 1972B)

2. The basic equipment, utilities, productive enterprises, installations and services essential for the development, operation, and growth of an organization, a city, or a nation. (Abrams 1971)

Inherent carrying capacity. See **Carrying capacity, ecological and Capability.**

Inherent suitability. See **Capability.**

Input-output analysis (Interindustry analysis, Leontief analysis)

1. A systematic technique for quantitatively analyzing the interdependence of producing and consuming units in an economy. It studies the interrelations among producers as

buyers of each other's outputs, as users of scarce resources and as sellers to final consumers. The technique has been useful for the study of the way in which the component parts of an economy fit together and influence each other, for short-run forecasting, and for policy guidance. (*U.S. Gen. Account. Off. 1969*)

2. A quantitative study of the interdependence of a group of activities based on the relationship between inputs and outputs of the activities. The basic tool of analysis is a square input-output table, interaction model, for a given period that shows simultaneously for each activity the value of inputs and outputs, as well as the value of transactions within each activity itself. It has especially been applied to the economy and the industries into which the economy can be divided. (*U.S. Forest Serv. 1972B*)

Inputs

1. A term used broadly to refer to anything that is taken in by or enters into the workings of a process or a system—e.g., as nutrients or energy into an ecosystem, effort or information into a planning process, silt into a stream, etc. (*After Webster 1963*)

2. The basic resources of land, labor, and capital required in carrying out an activity. (*U.S. Forest Serv. 1974A*)

Institutional land uses

All buildings, grounds and parking lots composing the facilities for educational, religious, health, correctional and military installations. (*Anderson, et al. 1972*)

Institutions

A significant and persistent element (as a practice or relationship) in the life of a culture that centers on a fundamental human need, activity or value, occupies an enduring and cardinal position within a society and is usually maintained and stabilized through so-

cial regulatory agencies (e.g., the special legal status of the social institutions of marriage and the family unit). (*Webster 1963*)

Also see **Institutions, social and Institutions, legal.**

Institutions, legal

A society's system of legal rules and principles. (*Webster 1963*)

The components of "legal institutions" that are usually of interest in land use planning include landownership patterns, administrative jurisdictions, land use patterns and the legal framework affecting planning decisions. (*W.W.*)

Institutions, social

1. A set of informal and formal rules, behaviors, and practices that deal with a specific basic function in society.

The five basic social institutions are: the economy, the political system, the educational system, the religious system, and the family. Each of these social institutions is seen as carrying out a basic function in society—the educational system is responsible for passing on knowledge to new members of the society, and for creating new knowledge in the society; the political system distributes power and maintains order; the economic system produces and distributes goods and services; the family establishes responsibility for the caring of the young, and, with the educational system, transmits knowledge to "new" members of society; and the religious system is concerned with basic questions of the meaning of life and with other social values.

Sociologists use the institutional approach as a kind of checklist in studying a society, as it is assumed that all societies (nations, regions, communities) find some way to carry out these basic functions. (*Gale 1975*)

2. A relatively prevalent way of

thought or action that centers around such basic social functions as marriage, government, or education.

Social institutions are common to all societies and are part of the customs of a people. **Culture** may be viewed as a synthesis of institutions, each functioning to establish **social norms** and give direction to human behavior. Thus institutions provide the forms for the activities of human beings. (O'Connell 1974)

Intangible value (Imponderable value)

Those resource yields which are not directly quantifiable, or if quantifiable, cannot be valued by market mechanisms. The net yields from resource use in this sense extends beyond the concept of secondary benefits, and includes psychic and indirect monetary benefits to the users. Normally intangible values accrue from the aesthetic, scientific, educational, historical or recreational aspects of the natural environment. (After Coomber and Biswas 1973)

Also see **Incommensurable values**.

Intensive recreation. See **Recreation, intensive**.

Interaction matrix (Matrix)

A table with actions, conditions, resources, effects, etc., listed along two perpendicular axes and a matrix structure so created where each position in the matrix corresponds to one element from each axis. By either marking or assigning values to the positions in the matrix structure interactions between pairs of elements (one from each axis) can be indicated. A matrix structure can be thought of as a rectangular cross-hatching, where each square in the cross-hatching belongs to one row and one column and corresponds to a position in the matrix structure or an element in the matrix. (E.C.T.)

Interdisciplinary approach

The utilization of a team of individ-

uals representing two or more areas of knowledge, learning, or skill focusing on the same subject.

This approach provides for integrating two or more mental processes into a common, problem-solving effort that is likely to be more effective than the independent thought processes of a single person trained or skilled in one area of knowledge. (U.S. Forest Serv., FSM 8211, Oct., 1973)

Interdisciplinary team

A group of individuals with different training assembled to solve a problem or perform a task. The team is assembled out of recognition that no one scientific discipline is sufficiently broad to adequately solve the problem. The members of the team proceed to solution with frequent interaction so that each discipline may provide insights to any stage of the problem and disciplines may combine to provide new solutions. This is different from a **multidisciplinary team** where each specialist is assigned a portion of the problem and their partial solutions are linked together at the end to provide the final solution. (E.C.T.)

Interest group. See **Special interest group** and **Pressure group**.

Interflow

That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface at some point of **infiltration**. (Soil Conserv. Soc. Amer. 1970)

Intermediate cutting (Stand tending)

Any removal of trees from a stand between the time of its formation and the harvest cutting. Generally taken to include **cleaning**, **thinning**, liberation and **improvement cuttings**, increment fellings, and sometimes even **salvage** and **sanitation cuttings**. (Ford-Robertson 1971)

Intermittent grazing

Grazing range or artificial pasture for indefinite periods at indefinite intervals. (*Amer. Soc. Range Manage.* 1964)

Intermittent stream

1. A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. It is dry for a large part of the year, ordinarily more than 3 months. (*Soil Conserv. Soc. Amer.* 1970)

2. Streams which, in general, flow during wet seasons and are dry during dry seasons. The **groundwater** table lies above the bed of the stream during the wet season but drops below the bed during dry seasons. Hence the flow is derived principally from surface runoff, but during wet seasons receives a contribution from ground water. In many arid areas the stream channels are always above the water table and therefore carry only surface runoff. Flow may also be interrupted by freezing of the ground-water to some depth below the stream bed in smaller streams. (*Wisler and Brater* 1959)

Also see **Ephemeral stream** and **Perennial stream**.

Interspecific competition. See **Competition**, definition 2.

Intraspecific competition. See **Competition**, definition 2.

Intrazonal soil. See **Soil horizon**, definition 2.

Intrinsic capability. See **Capability**.

Intrinsic resource

1. Philip H. Lewis' usage. The features of the natural environment which are recreation resources.

For example, the occurrence of significant topographic **relief**, rivers, lakes, wetlands, waterfalls, caves, etc.

(*Belknap and Furtado* 1967)

2. The term is now used to refer to any resource of natural origin—especially in contrast to resources of human origin (i.e., **extrinsic resources**).

See **Extrinsic resource** for man-made recreation resource features.

Intrinsic suitability. See **Suitability**, **intrinsic** and **Capability**.

Introduced species. See **Species**, **exotic**.

Invader. For range management usage see **Invader plant species**.

Invader plant species (**Invader**, **weed species**)

Range management usage. Plant species that were absent in undisturbed portions of the original vegetation and will invade under disturbance or continued **overuse**. (*Amer. Soc. Range Manage.* 1964)

Also see **Increase plant species** and **Decrease plant species**.

Inventory

1. The gathering of data for future use. (*U.S. Forest Serv.* 1972B)

2. The quantity or count of physical entities (such as trees, lakes, etc.) in an area. There are two basic types of inventories in land use planning.

A. Existing—measurement of what is actually “on-the-ground” (in terms of number), and

B. Potential—total identified undeveloped capability. (*U.S. Forest Serv.* 1972B)

Inverse condemnation. See **Condemnation**, **reverse**.

Irreplaceable asset. See **Unique resource**.

Irreversible effect

One of the categories of impacts specifically mentioned in section 102 of the **National Environmental Policy Act (NEPA)** for inclusion in the statement of environmental impacts required for Federal actions. Although not defined in NEPA it has been the subject of judicial review.

An irreversible effect is any effect of an action or inaction which (due to physical, biological, or socioeconomic constraints) cannot be reversed (by returning the object of the effect to its previous condition) within a reasonable length of time.

While a swamp which is channelled and drained after evolving for centuries may be returned to its pre-drained condition over many decades of being undisturbed, the time span involved is such that a reasonable man would consider the effect irreversible. Similarly, it may be physically possible to raze a city and plant a forest again, but a reasonable man would recognize that socioeconomic constraints would prevent this from happening. (*E.C.T.*)

Isochrons

1. Travel-time zones. (*U.S. Forest Serv.* 1971)
2. A concentric set of lines each of which joins distances with equal travel times from some central reference point of concern. (*C.F.S.*)

Isohyetal line

A line drawn on a map joining points that receive the same amount of precipitation. (*Amer. Geol. Inst.* 1962)

Isolated land. See **Alienated land.**

Jackson turbidity unit. See **Turbidity.**

JTU. Jackson turbidity unit. See **Turbidity.**

Just compensation

As regards property taken for public use, the term is comprehensive and includes all elements; but does not exceed **market value**. It is the value of

Issue

1. A controversial subject or topic. A point of debate or controversy. (*Webster* 1963)
2. A point in question of law or fact. A single material point of law or fact. (*Webster* 1963)
3. Something entailing alternatives between which to choose or decide. (*Webster* 1963)
4. A matter that is in dispute between two or more parties or that is disputed by the parties. (*Webster* 1963)
5. A well defined, discrete subject of controversy—such as whether the Supersonic Transport (SST) development program should or should not proceed because of the possibility that their exhaust gases might significantly reduce the ozone concentration in the stratosphere, or whether phosphates in detergents should be banned because of their alleged controlling role in the **eutrophication** of many water bodies. When the point of controversy can only be vaguely defined or when the causality relationships between use actions and undesirable results are more speculative than documentable the dispute is referred to as a **concern** rather than an **issue**. (*C.F.S.*)

J

property taken at the time of taking, plus compensation for delay in payment, if appropriate, and plus damages to the owner for value of use of property from date of taking possession to date of judgment if possession is taken by condemnation prior to judgment. (*U.S. Bur. Outdoor Recreation* 1974)

Also see **Eminent domain**, **Police power**, **Taking**.

K

Key area. For range management usage see **Key grazing area**.

Key facility

Usage in the defeated 1973 bill for a National **Land Use Policy and Planning Assistance Act**.

Public facilities, as determined by the state, on non-Federal lands which tend to induce development and urbanization of more than local impact, including but not limited to: (1) any major airport designed to serve as a terminal for regularly scheduled air passenger service or one of state concern; (2) major interchanges between the interstate highway system and frontage access streets or highways; major interchanges between other limited access highways and frontage access streets or highways; (3) major frontage access streets and highways, both of state concern; (4) major recreational lands and facilities; (5) major facilities on non-Federal lands for the development, generation, and transmission of energy (including such facilities as major powerplants, transmission lines, oil and gas pipelines, refineries, tank farms, etc. However, not included in this definition are any facilities for the extraction of fuels, such as

those associated with oil and gas drilling, strip or shaft mining, etc.). (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Key grazing area

That portion of a pasture or **grazing unit** which, because of its nature, location, and grazing use, serves to control the pattern of grazing use for the pasture as a whole. (*Soil Conserv. Soc. Amer. 1970*)

Key management species

Major **forage** species on which management should be based. (*Soil Conserv. Soc. Amer. 1970*)

Key site

Range management usage. Synonymous with **key area** except the area is restricted to a specific **range site**. (*Amer. Soc. Range Manage. 1964*)

Keystone species. See **Species, keystone**.

Key utilization species

Range management usage. Forage species whose use serves as an indicator to the degree of use of associated plant species. (*Amer. Soc. Range Manage. 1964*)

Key winter range. See **Range, key winter**.

L

Land

1. A term denoting the entire complex of surface and near-surface attributes of the solid portions of the surface of the earth which are significant to man. Water bodies occurring within land masses are included with land in some land classification systems. (*After Mabbutt 1968*)

2. U.S. Forest Service usage. For planning purposes land is defined as a specific area of the earth's surface. Its characteristics embrace all reasonably

stable, or predictably cyclic, attributes of the **biosphere** directly above and below this area including those of the atmosphere, the **soil** and underlying geology, the **topography**, the **hydrology**, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

As defined, the term "land" embraces all but the purely socioeconom-

ic (human) attributes of the environment. It is assumed that all approaches to interpretative **land classification** would, to a varying extent, take additional socioeconomic factors into account but these are not considered to be attributes of the "land" itself.

"Land" is a broader concept than soil. Thus, in developing interpretative land classification from **soil survey** data, additional aspects of the natural environment, notably macrotopography, vegetation, surface and ground-water hydrology, and **climate** as well as certain stable manmade features need investigation and integral interpretation. (*U.S. Forest Serv., FSM 8210, Oct. 1973*)

3. Economic theory usage. One of the major factors of production consisting of a good which is supplied by nature without the aid of man. The term may include not only the earth's surface, both solid land and water, but also anything that is attached to the earth's surface. Thus, all **natural resources** in their original state, such as mineral deposits, **wildlife**, timber, and fish are land within the technical meaning of the term; so are sources of energy, outside of man himself, such as water, coal deposits, and the **natural fertility** of the soil. (*Sloan 1961*)

4. In the most general sense, any ground, soil, or earth whatsoever. "Land" may include not only the soil or earth, but also things of a permanent nature affixed thereto or found therein, whether by nature, as water, trees, grass, herbage, and other natural or perennial products, growing crops or trees, minerals under the surface; as well as works constructed for use of water such as dikes, canals, etc. (*U.S. Bur. Outdoor Recreation 1974*)

5. The total natural and cultural environment within which production takes place; a broader term than "soil". In addition to soil, its attributes include other physical condi-

tions, such as mineral deposits, climate, and water supply; location in relation to centers of commerce, populations, and other land; the size of the individual tracts or holdings; and existing plant cover, works of improvement, and the like.

Some use the term loosely in other senses: as defined above but without the economic or cultural criteria especially in the expression "natural land" as a synonym for "soil"; for the solid surface of the earth; and also for earthy surface formations, especially in the geomorphological expression **landform**. (*Soil Conserv. Soc. Amer. 1970*)

Land, alienated

Lands of one ownership enclosed within boundaries of another ownership. Often refers to land in private ownership within the boundaries of public land. (*Amer. Soc. Range Manage. 1964*)

Land and Water Conservation Fund Act (78 Stat. 897, as amended; 16 U.S.C. 4601-4 to 4601-11, 23 U.S.C. 120 (Note))

Provides funds for and authorizes Federal assistance to the states in planning, acquisition, and development of needed land and water areas and facilities and provides funds for the Federal acquisition and development of outdoor recreation resources. (*After U.S. Forest Serv. 1974*)

Land and Water System

U.S. Forest Service usage. One of the six "systems" established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act** of 1974. It has grouped its various programs into these six "systems", each of which incorporates all the activities

concerned with developing and managing a specific resource. (*After U.S. Forest Serv. 1974A*)

The role of this system is to protect, conserve, and enhance the basic resources of air, soil, and water on forest and range land. It provides the base on which the other resources grow. Activities on National Forest land include land-use planning, administration of special land uses, easements, and land adjustments, and management of mineral areas in addition to the protection, conservation, and enhancement role. (*U.S. Forest Serv. 1974A*)

The six "systems" are: "Land and Water", **Timber Resource**, **Outdoor Recreation and Wilderness**, **Rangeland Grazing**, **Wildlife and Fish Habitat**, and **Human Community Development**.

Land capability

U.S. Soil Conservation Service usage. The inherent ability of land to be used without permanent damage. Land capability, as ordinarily used in the United States, is an expression of the effect of physical land conditions, including climate, on the total ability to be used without damage for crops that require regular tillage, for grazing, for woodland, and for wildlife.

Land capability involves consideration of (1) the risks of land damage from erosion and other causes and (2) the difficulties in land use owing to physical land characteristics, including climate. (*After Soil Conserv. Soc. Amer. 1970*)

Also see **Capability** and **Suitability** for comments on the preferred usage of those terms.

Land capability class

U.S. Soil Conservation Service usage. One of the eight classes of land in the **land capability classification** system of the Soil Conservation Service.

The eight land capability classes in this system are distinguished according

to the risk of land damage or the difficulty of land use. The first four classes distinguish land inherently able to be used for cultivation and other uses. (I). Soils in class I have few limitations that restrict their use. (II). Soils in class II have some limitations that reduce the choice of plants or require moderate conservation practices. (III). Soils in class III have severe limitations that reduce the choice of plants or require special conservation practices, or both. (IV). Soils in class IV have very severe limitations that restrict the choice of plants, require very careful management, or both. The second four classes distinguish land generally inherently unable to be used for cultivation (without major treatment). (V). Soils in Class V have little or no erosion hazard but have other limitations, impractical to remove, that limit their use largely to **pasture**, **range**, **woodland**, or **wildlife food and cover**. (VI). Soils in class VI have severe limitations that make them generally not able to be used for cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover. (VII). Soils in class VII have very severe limitations that make them not able to be used for cultivation and that restrict their use largely to grazing, woodland, or **wildlife**. (VIII). Soils and landforms in class VIII have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or aesthetic purposes. (*Soil Conserv. Soc. Amer. 1970*)

Land capability classification

U.S. Soil Conservation Service usage. A grouping of kinds of soil into special units, subclasses, and classes according to their **capability** for intensive use and the treatments required for sustained use. (*Soil Conserv. Soc. Amer. 1970*)

Land capability map

U.S. Soil Conservation Service usage. A map showing **land capability units**, **land capability subclasses**, and classes or a soil survey map colored to show **land capability classes**. (*Soil Conserv. Soc. Amer.* 1970)

Also see **Soil map**.

Land capability subclass

U.S. Soil Conservation Service usage. Groups of **land capability units** within classes of the **land capability classification** system that have the same kinds of dominant limitations for agricultural use as a result of soil and climate.

For example, some soils are subject to erosion if they are not protected, while others are naturally wet and must be drained if crops are to be grown. Some soils are shallow or droughty or have other soil deficiencies. Still other soils occur in areas where climate limits their use.

The four kinds of limitations recognized at the subclass level are: risks of erosion; wetness, drainage, or overflow; other root zone limitations; and climatic limitations.

The subclass provides the map user information about both the degree and kind of limitation. (*Soil Conserv. Soc. Amer.* 1970)

Land capability unit

1. U.S. Soil Conservation Service usage. A group of soils that are nearly alike in inherent ability to be used for plant growth and in their responses to the same kinds of soil management.

Capability units provide more specific and detailed information for application to specific fields on a farm or ranch than the "subclass" of the **land capability classification**. (*Soil Conserv. Soc. Amer.* 1970)

Land capability zoning. See **Zoning, land capability**.

Land classification

1. Land classification is the process

whereby the complex of surface and near-surface attributes of the solid portions of the earth's surface are identified and organized into some system of mappable units according to some set of criteria or principles for relatedness.

"Land classification" creates a framework of generalization about the complexity of "land" properties which enables common characters to be defined and described, and units with similar properties to be regarded as equals although geographically separate.

Classification is a prerequisite if there is to be any transfer of knowledge about the relationships between land properties and land use **suitability** and **capability** from one unit to others—i.e., if there is to be any element of expectation in land use planning. (*After Mabbutt 1967*)

2. The arrangement of land units into various categories based on the properties of the land or its inherent capability for some particular purpose. (*Soil Conserv. Soc. Amer.* 1970)

Land district

Canada Biophysical Land Classification System Usage. A relatively homogeneous unit of land characterized by a distinctive pattern of **relief**, **geology**, **geomorphology** and regional vegetation. (*Bajzak 1973*)

This is the second largest of the four classification levels of that system. The largest unit is the **land region** and the two smaller units in order of decreasing size are **land system** and **land type**.

Land evaluation (Terrain evaluation)

The assessment of the inherent **capability** and managed **suitability** of land for man's use in agriculture, forestry, engineering, hydrology, regional planning, recreation, etc. (*After Stewart 1967*)

Land feasibility. See **Feasibility**.

Land form

The form of the surface of the land.

The three-dimensional shape of the surface of the ground.

"Land form" may have a different meaning than **landform** when used in geomorphological contexts. "Land-form" is always used for surface features whose origin can be attributed to particular geological processes or particular structures. (*After Savigear 1965*)

Landform

1. Term used to describe the many types of land surfaces which exist as a result of geological activity, such as a plateau, plain, basin, mountain, etc. (*U.S. Forest Serv. 1972B*)

2. A feature of the earth's surface with distinctive form characters which can be attributed to the dominance of particular processes or particular structures in the course of its development and to which the feature can be clearly related. (*Savigear 1965*)

3. **Land form** may have a different meaning than "landform" when used in geomorphological contexts. "Land form" is sometimes used when referring only to the three dimensional shape of the ground surface—without any reference to the processes responsible for that shape. (*Savigear 1965*)

Land management

The intentional process of planning, organizing, **programming**, coordinating, directing, and controlling land use actions. (*After U.S. Forest Serv. 1971*)

Land, marginal

Land of questionable economic abilities to be used for a specific purpose. (*Amer. Soc. Range Manage. 1964*)

Land region

Canada Biophysical Land Classification System Usage. An area of land with a certain type of vegetation

which manifests a distinctive climate. (*Bajzak 1973*)

This is the largest unit of the four classes of that system. The other three classes in order of decreasing size are **land district**, **land system** and **land type**.

Land resource area

1. U.S. Forest Service usage. Broad geographic areas having similar soil, climatic, geologic, vegetative and topographic features. (*U.S. Forest Serv. 1972B*)

2. An area of land reasonably alike in its relationship to agriculture with emphasis on combinations and/or intensities of problems in soil and water conservation.

It is ordinarily larger than a **land resource unit** and smaller than a **land resource region**. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Conservation**, definition 1.

Land resource region

A generalized grouping of **land resource areas** reflecting regional relationships to agriculture with emphasis on soil and water conservation. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Conservation** definition 1.

Land resource unit

A subdivision of a **land resource area** with emphasis on a specialized type of agriculture, intensities, or problems in soil and water conservation.

It has a narrower range in relationship to agriculture (than a **land resource area**) with emphasis on soil and water conservation. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Conservation** definition 1.

Land sales or development project. For usage of this term in the defeated 1973 bill for a National **Land Use Policy and Planning Assistance Act** see **Project**.

Landscape

1. An areal entity which is a composite of all of the characteristics that distinguish a certain area on the earth's surface from other areas. (*Holland 1970*)

2. An expanse of natural scenery seen by the eye in one view. (*Webster 1963*)

3. An area made up of a distinct association of forms, both physical and cultural. (*Stamp 1961, citing Sauer 1925*)

4. The sum total of the characteristics that distinguish a certain area on the earth's surface from other areas. These characteristics are a result not only of natural forces but of human occupancy and use of the land. (*U.S. Forest Serv. 1963*)

Landscape, canopied

The type of visual landscape to be found under an extensive, continuous crown cover of trees—as within a forest. The overhead foliage and branches define the ceiling plane and the perspective closure of tree stems or screens of understory shrubs and young trees or land forms define the side enclosures. (*After Litton 1968*)

This is one of the six general types in Litton's scenic composition classification system. The others are **panoramic landscape**, **feature dominated landscape**, **enclosing landscape**, **focal landscape**, and **detailed landscape**.

Landscape, cultural

1. The aspect of the face of the earth which results from the presence of man—the natural landscape modified by man. (*Stamp 1961*)

2. The material features, in compact areal association, which are the result of the transformation of a natural landscape through human occupancy. (*Stamp 1961*)

Landscape, detailed

The close view of objects or features, particularly surface character-

istics, color or touchable nature. There is little or no sense of space and attention is restricted to the intimate details of features. (*Litton 1966*)

This is one of the six general types in Litton's scenic composition classification system. The others are **panoramic landscape**, **focal landscape**, **feature-dominated landscape**, **enclosing landscape** and **canopied landscape**.

Landscape, enclosing

An outdoor space (rather than strictly a view type) with definite visual sidewalls or edge lines (formed by **terrain**, tree, lake or meadow surfaces) which enclose or define the field of vision.

A small scale landscape in which the viewer has a sense of presence by being within the **foreground** which is most apt to form the floor of the space.

"Enclosing landscapes" are always seen from a viewing position below the tops of the surrounding sidewalls. (*Litton 1966*)

This is one of the six general types in Litton's scenic composition classification system. The others are **panoramic landscape**, **focal landscape**, **feature-dominated landscape**, **detailed landscape** and **canopied landscape**.

Landscape, feature-dominated

A view in which a single feature (or landmark), either natural or man-made, dominates the landscape because of sharp contrast with the general surroundings.

Often, but not necessarily, a landscape dominated by the **middle-ground** plane in the field of vision.

Feature-dominated landscapes may be recognized from any viewing position—i.e., above, level with or below the feature or its surrounding landscape. (*Litton 1966*)

This is one of the six general types in Litton's scenic composition classification system. The others are **pan-**

oramic landscape, focal landscape, enclosing landscape, detailed landscape, and canopied landscape.

Landscape, focal

A view characterized by convergent lines which lead the eye to the principal point of their apparent origin.

Parallel lines in perspective will appear to have a focal point origin at the horizon. The eye's attention will be concentrated upon and follow these dominant lines toward the horizon or their focal point.

"Focal landscapes" are always seen from a viewing position level with or above the horizon line. (*Litton 1966*)

This is one of the six general types in Litton's scenic composition classification system. The others are panoramic landscape, feature-dominated landscape, enclosing landscape, detailed landscape and canopied landscape.

Landscape, panoramic

A landscape viewing situation characterized by an unobstructed or complete view of the area in all directions or a continuous series of scenes extending to the distant horizon.

The visual feeling is one of expanding or unbounded space, receding directly ahead toward the limits of distance on visibility and also extending laterally to the limits of peripheral vision. Although indicating the availability of a view in every direction, inherent physiological limitations on the extent of what an observer can see without turning the head suggests that a possible view of 180 degrees is a more likely condition for defining a "panoramic landscape".

The term should be reserved for use where distant or background scenes are under observation, not horizontal scene compositions in the middle-ground or foreground. (*After Litton 1966*)

This is one of the six general types

in Litton's scenic composition classification system. The others are feature-dominated landscape, enclosing landscape, focal landscape, canopied landscape and detailed landscape.

Landscape planning

A portion of the land use planning process which deals with physical (i.e., biological, geological and hydrologic) values, aesthetic and cultural (i.e., historical and anthropological) values and with the relationships between these values and land uses. (*Fabos, et al. 1973*)

Landscape unit

G.A. Hills' land evaluation usage. A regrouping of patterns of physiographic site types and physiographic site phases into larger (16 sq. mi. minimum) units to facilitate the making of broad scale planning decisions. (*After Belknap and Furtado 1967*)

Land sensitivity. See Sensitivity, land.

Landslide (landslip)

1. Downslope movement of a relatively dry or coherent mass of earth and/or rock at a rate fast enough to be readily perceived. (*After Amer. Geol. Inst. 1962*)

Readily perceptible downslope movement of a wet, incoherent mass of earth is termed a mudslide. (*C.F.S.*)

2. The failure of a slope in which the movement of the soil mass takes place along an interior surface of sliding. (*Soil Conserv. Soc. Amer. 1970*)

Landslide hazard

Some evaluation (almost always qualitative and relative to adjacent locations) of the chance that a landslide will occur on a given site. (*C.F.S.*)

Landslip. See Landslide.

Land stratification. See Stratification.

Land subdivision. See Subdivision.

Land, submarginal

1. Land that does not return

enough to pay costs of operation in a specific use. (*Soil Conserv. Soc. Amer. 1970*)

2. Land which is economically incapable of sustaining indefinitely a certain use or ownership status. (*Amer. Soc. Range Manage. 1964*)

Land suitability. See **Suitability.**

Land system

1. Canada Biophysical Land Classification System usage. An area of land with a recurring pattern of **land form** having homogeneous soil characteristics and supporting a particular type of vegetation. (*Bajzak 1973*)

The second smallest of the four classification levels of that system. The other three classes in order of decreasing size are **land region**, **land district** and **land type**.

2. U.S. Forest Service usage. Typically used to categorize all the land in an area into each of various **hierarchical** levels by the application of increasingly more specific delineation criteria at successively lower (i.e., smaller units) levels in the system. Each set of delineation criteria is unique to its classification level but is also logically and systematically related to the other higher and/or lower levels in that classification system.

A hierarchical framework of land type units. (*After Nelson 1975*)

Land systems inventory

U.S. Forest Service usage. A **land stratification** system based on geomorphic principles. An understanding of geologic structure, **land form** genesis and **geomorphic processes** (as reflected in land surface form and features), individual kinds of soil and the factors which determine the behavior of ecosystems (i.e., climate, vegetation and animal life, relief, **parent materials** and time), is used as the basis of this classification system.

The various hierarchical levels in the "land systems inventory" classification

scheme are: (1) the "physiographic province" (a division of the land in which the pattern of topographic elements of altitude, **relief** and type of land forms are uniform throughout an area of several thousand square miles or larger); (2) the "section" (land units in which the combined factors of geologic structure, geomorphic processes, climate and time have been essentially the same and thus produced a uniform pattern of topography over areas of hundreds to several thousand square miles); (3) the "subsection" (the smallest land unit which can be identified using the basic criteria of uniform geologic factors and climate operating over time to delineate essentially uniform areas of tens to hundreds of square miles); (4) the "land type association" (units tens of square miles in size over which the uniformity of geomorphic processes has produced different types of landscapes which can be visually identified on maps, air photos or on the ground); (5) the "landtype" (visually identifiable unit areas of a tenth to one square mile resulting from homogeneous geomorphic and climatic processes which have produced defined patterns of soils and vegetation potentials); (6) the "landtype phase" (.01 to .1 square mile areas delineated on the basis of being characterized by uniform, specific kinds of soils or **soil phases** or sometimes on the basis of **physiographic**, vegetative or **bedrock** characteristics) and; (7) the "site" (areas of less than an acre defined and characterized by the occurrence of individual kinds of soils or discrete **plant communities**. (*After Wertz and Arnold 1972*)

Land tenure

1. The holding of land or the right to hold it. (*Abrams 1971*)

2. The holding of land and the rights that go with such holding, including all forms of holding from fee

simple title (embracing all possible rights within the general limitations imposed by the government) to the various forms of tenancy or holding of land owned by another. (*Soil Conserv. Soc. Amer.* 1970)

3. The rules by which members of a social group customarily exercise control, inheritance, and usage rights over land. The rules cover such practices as individual ownership, group ownership with allocation procedures, and various kinds of lending possibilities. (*O'Connell* 1974)

Also see **Property rights**.

Land type

Canada Biophysical Land Classification System usage. An area of land having a fairly homogeneous combination of soil features at a level corresponding to the **soil series**—i.e., a group of soils having horizons similar in distinguishing characteristics and arrangement in the profile and developed from the same parent material and chronological sequence of vegetation.

The land type is the basic biophysical land unit that can be interpreted to provide land evaluation data useful for planning and development. The mapping scale at the land type level ranges from 1/20,000 to 1/10,000. The dominant ecological variables are soil moisture regime, physical and chemical soil properties and **microtopography**. (*Wells and Roberts* 1973)

The units in that classification system, in order of decreasing size are **land region**, **land district**, **land system** and **land type**.

Landtype (Watertype)

1. G. A. Hills' land classification usage. Units created by isolating areas of differing landform, geologic composition and water content within the **site region**.

A "landtype" is a subdivision of a "site region" and determined by certain soil properties (such as texture,

depth, mineral composition, water content, etc.) and nature of parent material in large-scale land features. (*After Belknap and Furtado* 1967)

The second largest unit in Hills' land classification system. The various levels, in order of decreasing size are **site region**, "landtype", **physiographic site class**, **physiographic site type** and **physiographic site phase**.

2. U.S. Forest Service usage. Visually identifiable unit areas resulting from homogeneous **geomorphic** and climatic processes and having defined patterns of soils and vegetative potentials.

Landtype units range in size from about one-tenth to one square mile. Their size and composition depend upon the significance of physical characteristics which can be readily interpreted to identify hazard, capability and productivity potentials that are reliable for land use planning purposes.

Landtype units generally have uniform management response characteristics and so can be used to identify areas for which **zoning** and resource allocation decisions can be made. (*After Wertz and Arnold* 1972)

Also see **land system**, definition 2.

3. Veatch's usage of "natural landtype". A natural division based upon the intrinsic nature of the soil, the nature of the **soil association** or **soil complex**, the topography, the natural drainage and the native vegetation. (*After Veatch* 1937)

Land units

G. A. Hills' land evaluation usage. A portion of a **landscape unit** — i.e., groupings of **physiographic site types** and **physiographic site phases** into 16 sq. mi. minimum units—with special significance for some specific use. (*After Belknap and Furtado* 1967)

Land use

The occupation or reservation of land or water area for any human activity or any defined purpose. It also

includes use of the air space above the land or water. (*Calif. Coun. Intergov. Relat.* 1973)

Also see **Land use type**.

Land use allocation

The committing of a given area of land or a resource to one or more specific uses—e.g., to campgrounds, wilderness areas. (*U.S. Forest Serv., FSM 8200R-8*)

Land use capability. See **Capability**.

Land use constraints

Any factor that may act to reduce management options or discourage various uses—e.g., erosive soils, unstable slopes, steep topography, presence of archeological or historic remains. (*U.S. Forest Serv., Colville Natl. Forest 1974*)

Land use feasibility. See **Feasibility**.

Land use plan

1. The concrete expression in map and text form of objectives which are considered desirable by a governing body with the power to approve and implement the plan. (*Hills, Love and Lacate 1970*)

2. U.S. Bureau of Land Management usage. A "land use plan" is a coordinated composite of information, ideas, policies, programs, and activities related to existing and potential uses of land within a given area, starting with the **planning unit**, extending through an integrated system of planning units that comprise a district and ultimately becoming part of a land use plan for all Bureau land holdings within the state and nation.

It, in part, identifies where these activities take place or where additional activities could take place under future conditions or circumstances, either under Bureau jurisdiction or the control by other public agencies or private parties.

The total comprehensive land use plan provides the basis for the more

complete coordination of existing and future Bureau programs and activities with those either under way or contemplated on land adjoining public lands. (*Eisner 1969*)

3. "Land use plans" will serve as (1) a basis for the implementation of action plans and (2) the foundation for future planning efforts, as well as (3) a guide for direct actions and decisions. (*Rupp 1974*)

4. A community plan outlining proposed future land uses and their distribution. (*Soil Conserv. Soc. Amer.* 1970)

Land use planning

1. Land use planning is the process of organizing the development and use of lands and their resources in a manner that will best meet the needs of people over time while maintaining maximum flexibility for a dynamic combination of resource output for the future. (*After Camp 1974*)

2. Land use planning is a process which allocates geographically fixed resources to a variety of uses. (*After Camp 1974*)

3. Land use planning is the never-ending process of inventorying and assessing the status, potentials, and limitations of a particular geographic area and its resources; interacting with the populations associated and/or concerned with the area to determine their needs, wants, and aspirations for the future; hypothesizing patterns of use compatible with both the area's **capabilities** and human needs and wants; proposing and assessing the consequences of, and implementing the best of alternatives for achieving the desired patterns of use, documenting the history of use to enable comparison of expected and experienced consequences; and repeating the entire process over and over to account for changing environmental status, changing technology, and

changing human wants. (*After Camp 1974*)

4. The ordering of future activities in space. (*Ackerman 1963*)

5. The process by which decisions are made on future land uses, over extended time periods, that are deemed to best serve the **general welfare**. (*Soil Conserv. Soc. Amer. 1970*)

Land Use Policy and Planning Assistance Act

1. U.S. Senate bill 268, 93rd Congress usage. This proposed act was defeated in committee in February 1974.

The Congress, recognizing that the Nation's land is its most valuable national resource and that the maximum benefit to all from this resource can be achieved only with the development and implementation of sound and coordinated land use policies, declares that it is the continuing policy of the Federal government to cooperate with and render assistance to state and local governments in the development and implementation of the policies which will govern the wise and balanced use of the Nation's land resource. The purpose of this Act is to establish a National land use policy, to authorize the Secretary of the Interior to make grants to assist the states to develop and implement state land use programs, to coordinate Federal programs and policies which have a land use impact, to coordinate planning and management of Federal lands and planning and management of adjacent non-Federal lands, and to establish an office of land use policy administration in the Department of the Interior.

The purpose of the Act is to encourage comprehensive, balanced—not **functional planning**. Thus, whenever levels of government below the state government are to be included in the important decisionmaking and financial assistance activities in the Act, the language of the Act limits the governments involved to **general purpose lo-**

cal government. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

2. U.S. Senate bill 924, 93rd Congress usage. This Nixon-Administration-proposed act was defeated in Congress.

This Act was first proposed in 1971 and followed the concepts contained in the draft "model land development code" developed by the American Law Institute (ALI). That code called for the states to take a highly selective approach, focusing on land use questions of more than local significance. Under the ALI code some 90 percent of all land use questions would continue to be disposed of by local agencies without interference from state government. Through compromise, since their introduction, the two land use planning bills have become quite similar, and this proposed Act was abandoned in favor of the Senate bill 268 version. (*After Carter 1973*)

Land use practice (Discrete land use operation)

1. A term used to refer to the various kinds of altering actions and/or activities associated with or utilized in facilitating or making possible different types of land uses—e.g., clearing of vegetation, land grading, paving, landscaping, fencing, fertilizing, irrigating, etc.

"Land use practices" are distinct from **land use types**. "Land use types" is a classification system based on the purpose for which the land is being used—e.g., timber production, range, second home subdivisions, farming, heavy industry, etc. "Land use types" are bundles of more or less shared "land use practices"—though the precise types and amounts of practices that are utilized in conjunction with a specific use type may vary from one specific instance to another.

"Land use practices" is an alternative to "land use types" as a way of classifying for study and/or regulation

the problems created by use. By restricting practice alternatives the problems associated with specific uses can sometimes be eliminated or reduced while not necessarily preventing use—because there may be an alternative acceptable practice. (*C.F.S.*)

Land use suitability. See **Suitability.**

Land use survey

A survey of the uses to which land is put in a particular area, usually summarized both in map form and statistically. (*Abrams 1971*)

Land use type (Land use)

1. U.S. Forest Service usage. The primary use of a tract of land—e.g., crops, pasture, forest, urban and other. (*U.S. Forest Serv. 1972B*)

2. A classification system based on the purposes for which land is being used—e.g., timber production, range, second home subdivisions, farming, etc. “Land use types” are bundles of more or less shared **land use practices**—though the precise types and amounts of practices that are utilized in conjunction with a specific use type may vary from one specific instance to another. (*C.F.S.*)

Large-lot zoning. See **Zoning, large-lot.**

Large scale development

1. Usage in the defeated 1973 bill for a National **Land Use Policy and Planning Assistance Act**. Private development on non-Federal lands which, because of its magnitude or the magnitude of its effect on the surrounding environment, is likely to present issues of more than local significance in the judgment of the state.

In determining what constitutes “large scale development” the state is asked to consider, among other things, the amount of pedestrian or vehicular traffic likely to be generated; the number of persons likely to be present; the potential for creating environmental problems such as air, water, or noise

pollution; the size of the site to be occupied; and the likelihood that additional or subsidiary development will be generated.

The purpose of this definition is to focus on the size and nature of the project rather than on ascertaining the precise individual or organization which is the **developer**. First, the definition of the project insures that it is of a size which would have significant impacts upon the environment and urban services. Second, it provides that the state develop a program for those projects only in remote, rural or other areas where local government is ill-equipped to regulate the project itself. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Law, common (Precedent law)

1. A body of rules based on judicial decisions rather than legislation.

It is the basis of the Anglo-American legal tradition. The “common-law” judge relies on judicial decisions of the past in rendering his rulings. Under the “common-law” approach the law can change gradually at the hands of the judges to meet the changes in society. In the United States the “common-law” system is evident in the supremacy of the judiciary in determining the constitutionality of legislation. In contrast, the system of civil law prominent on the continent of Europe is based on Roman law and later codes of legislation. (*O’Connell 1974*)

2. The system of unwritten law (as distinguished from written statute laws) that has been declared in written opinions by judges and is based either on the general customs or on reason and fixed principles of justice. (*Webster 1963*)

Law, natural

1. An abstract concept of law based on the relation between God, man, and nature. An ideal higher than

man-made law, it forms the basis of justice in the ethical sense. It embodies such ideas as the existence of a universal order governing all men and the unalienable rights of the individual. (O'Connell 1974)

2. A body of law derived from nature and binding upon human society in the absence of or in addition to institutional law. (Webster 1963)

3. The body of rules or customs derived from the general maintenance of human society. (Webster 1963)

LD₅₀. See Median lethal dose.

Leasable mineral. See Mineral, leasable.

Legal institution

A society's system of legal rules and principles. (Webster 1963)

Leontief analysis. See Input-output analysis.

Lexicography

1. The editing or making of a dictionary. (Webster 1963)

2. Decision theory usage. A method of choosing among alternatives based on an analogy to the way words are arranged in a dictionary. A single objective or attribute is rated as most important, and alternatives are ranked according to how well they satisfy this objective. If an alternative is clearly superior in this attribute to other alternatives it is selected. Otherwise the second most important attribute is used to rank the top alternatives from the first ranking. This process continues, constantly reducing the number of alternatives ranked and ranking by less important attributes, until a single project is clearly superior for the attribute being used to rank the alternatives. (After Mac Crimmon 1968)

Life cycle

1. The successive stages through which an organism passes from the spore or fertilized egg of one genera-

tion to the spore or fertilized egg of the next generation.

A continuous, descriptive account of a life cycle is called the life history of an organism. (Ford-Robertson 1971)

2. The series of stages in the form and mode of life of an organism between successive recurrences of a certain primary stage, such as the spore, fertilized egg, seed or resting cell. (Wash. State Univ., Coop. Ext. Serv. 1972)

Life history

A continuous, descriptive account of the life cycle of an organism. (Ford-Robertson 1971)

Life quality index. See Quality of life and Index.

Life style

1. A characteristically different way of living which may be an individual variant within the cultural mainstream or may be an individual expression of a subculture. "Life styles" are generally expressed through the means of economic sustenance, dwelling site and type, types of group associations, and social practices such as family form, religious practices, sexual mores, and style of dress, type of diet, etc.

The "life style" which is most common for a given culture is sometimes referred to as the "mainstream life style" and those which are uncommon (culturally unusual, atypical) as "alternative (or subculture) life styles". (L.W.)

Life zone

1. An altitudinal or latitudinal biotic region or belt with distinctive faunal and floral characteristics. (Hanson 1962)

2. Areas of land classified into gross habitat types by a combination of elevational and climatic zones and other factors which determine the

type of animal and plant life found in them—e.g., the Upper Sonoran, Transition, Canadian, Hudsonian and Alpine life zones. (After U.S. Forest Serv., FSM 2800 R-8, date unknown)

Light grazing. See **Grazing, light.**

Limiting factor

1. Any environmental factor whose presence, absence or abundance is the main factor restricting the distribution, numbers or condition of an organism. (After Durrenberger 1973, SESCO, et al. 1973)

2. The environmental influence by which the limit of tolerance of an organism is first reached and which, therefore, acts as the immediate restriction to one or more of its functions or activities or in its geographic distribution. (Hanson 1962)

Limits

Range management usage. The number of livestock which may be grazed under provisions of a **grazing preference**. (Amer. Soc. Range Management. 1964)

Linear perspective. See **Perspective, linear.**

Linear programming

1. A mathematical method used to determine the most effective allocation of limited resources between competing demands when both the objective (e.g., profit or cost) and the restrictions on its attainment are expressible as a system of linear equalities or inequalities (e.g., $y=a+bx$). (U.S. Forest Serv. 1972B)

2. A **deterministic model** which assumes linear behavioral relationships and in which an optimal solution is sought (by maximizing or minimizing) subject to one or more limiting constraints.

Linear programming is used to determine the best or optimum use of resources to achieve a desired result when the limitations on available re-

sources can be expressed by simultaneous linear equations. (U.S. Gen. Account. Off. 1969)

3. A class of **programming techniques** used to analyze or solve problems in which the linear function of a number of variables is to be maximized or minimized when those variables are subject to a number of constraints in the form of linear inequalities. (U.S. Forest Serv. 1972B)

Litter (Forest litter, Leaf litter)

The uppermost layer of organic debris on the ground under a vegetation **cover**—i.e., essentially the freshly fallen or only slightly decomposed vegetable material, mainly from foliage but also bark fragments, twigs, flowers, fruits, etc. (After Ford-Robertson 1971)

Littoral

1. Belonging to the shore, as of seas and the great lakes; **riparian** proprietors on a stream or small pond are analogous to littoral proprietors on a sea or lake. (U.S. Bur. Outdoor Recreation 1974)

2. Of or pertaining to the shore; existing, taking place upon or adjacent to the shore. Applied loosely and generally to the seashore as well as to the shores of lakes and rivers. (Stamp 1971)

3. Also see **Riparian**.

Lobbying

1. Activity engaged in by individuals or organizations (directly or through hired representatives) that is directed at the various elements of government in an attempt to influence legislation or policies in a way that is favorable to the interests of the lobbying group.

A potential source of conflict lies in the fact that the public, viewed as a collection of individuals, is seldom represented in such activities. (O'Connell 1974)

Local economic effects

Effects of an action or inaction on dollar market transactions in the immediate area of the action or inaction. The "local" area would include an area encompassing the primary sources of employment and retail outlets for basic commodities such as food utilized by the people of that area. (*E.C.T.*)

Local government

Usage in the defeated 1973 bill for a national **Land Use Policy and Planning Assistance Act**. Any **general purpose local government** or any regional combination thereof, or, where appropriate, any other public agency which has land use planning authority. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Local overgrazing

Overgrazing in localized areas on a range, as, for example, near watering places. (*Amer. Soc. Range Manage. 1964*)

Local species. See **Species, local.**

Locatable mineral. See **Mineral, locatable.**

Locatable mineral deposits. See **Minerals, locatable.**

Location (Mineral location)

The acts or series of acts pursuant to the general mining laws by which the right of exclusive possession of **locatable mineral** deposits is vested in the locator. (*U.S. Forest Serv., FSM 2811.1.F, Sept., 1958*)

A **mining claim** is sometimes called a "location" but those terms may often mean different things—e.g., "mining claim" may refer to a parcel of land containing soil or rock which has value because of its chemical composition, while "location" is the act of appropriating such land according to certain established rules. (*Thrush 1968*)

Also see **Minerals, locatable.**

Location theory

The theory which attempts to ex-

plain and predict the location of individual, commercial, and industrial development. It is important to the planner for predicting population and industrial distributions which would result from alternative plans. (*E.C.T.*)

Lode mining. See **Mining, lode.**

Logged-over forest

A forest in which most or all of the merchantable timber has been cut. (*Soil Conserv. Soc. Amer. 1970*)

Logging

The cutting and extraction of timber, particularly logs. (*Ford-Robertson 1971*)

In imprecise usage **logging**, **harvesting**, and **silviculture** are used seemingly interchangeably by different people, often with vehemence as to which is the correct term in a given situation. According to Ford-Robertson (1971) "silviculture" has as its primary concern the establishing, growing, and tending of forests. "Harvesting" and "logging", however, deal specifically with the extraction of resources from the forest; with "logging" restricted to the cutting and extraction of timber (wood other than fuel wood after **primary conversion**) and "harvesting" expanding this to include the cutting, initial processing if any, and extraction of any forest product. (*After Ford-Robertson 1971*)

Logging, aerial

A system for hauling timber from the stump to a collecting point which employs aerial means of transportation—e.g., balloons or helicopters. (*Ford-Robertson 1971*)

Logging, cable

A method for transporting logs from stumps to collecting points which utilizes a cable system as the main device for moving them. (*Ford-Robertson 1971*)

For some of the different types of "cable logging" see **Logging, skyline**;

Logging, high-lead; and Logging, ground-lead.

Contrast with **Logging, tractor**.

Logging, ground-lead (Low-lead cable logging)

A method for transporting logs from the stumps to a collecting point by dragging them along the ground with a powered cable passing through a block fastened close to ground level. (*After Ford-Robertson 1971*)

Logging, high-lead

A method for transporting logs from the stumps to a collecting point by using a powered cable, passing through a block fastened high off the ground, to lift the front end of the logs clear of the ground while dragging them. (*After Ford-Robertson 1971*)

Logging, low-lead. See **Logging, ground lead**.

Logging, skyline (Skyline yarding)

A method for transporting logs from stumps to collecting points that uses a heavy cable stretched between high points (such as in tall trees braced with guy lines) to function as an overhead track for a load carrying trolley. Logs are lifted up by cables or other devices attached to the trolley and powered cables are used to move the load back and forth along the main cable. (*After Ford-Robertson 1971*)

"Skyline logging" is a particular type of cable logging.

Logging, tractor

Any logging method which uses a tractor as the motive power for transporting logs from the stumps to a collecting point—whether by dragging or

carrying the logs. (*Ford-Robertson 1971*)

Contrasts with **Logging, cable**.

Long-range planning

1. U.S. Forest Service usage. Planning for the period covered by basic resource management plans, usually ten or more years. (*U.S. Forest Serv. 1972B*)

2. Planning in the long-range sense is the selection or identification of the overall, long-range objectives. The analysis of various possible courses of action in terms of their relative costs and accomplishments or benefits is then used to decide on which courses of action to follow in order to achieve those objectives. (*U.S. Gen. Account. Off. 1969*)

3. Planning for a future more than 5 years distant. (*After U.S. Forest Serv. 1972B*)

4. The continuous process of making present (risk-taking) decisions systematically and with the best possible knowledge of their futurity for some 10 to 30 years, organizing systematically the efforts needed to carry out these decisions, and measuring the results of these decisions through organized, systematic feedback. The scheduling of needed improvements is on a less detailed basis with more flexible timing and a recognition of the adjustments and re-analysis that the passage of time will inevitably compel. (*After Winfrey and Zellner 1971*)

"Long range planning" does not deal with future decisions. It deals with the future attainment of present decisions. (*Drucker 1959*)

Low-lead logging. See **Logging, ground lead**.

Macroclimate (Regional climate)

The general large-scale climate of a large area or country, as distinguished from the **mesoclimate** and **microclimate**. (*Huschle 1959*)

Macroeconomics

Economic studies or statistics that consider aggregates of individuals or groups of commodities; for example, total consumption, employment, or income. (*Sloan 1961*)

Also see **Microeconomics**.

Majority determinism

A point of view in resource planning which advocates making resource use and allocation decisions on the basis of some sort of a simple expression of the most popular choice of use or mixes of uses. (*C.F.S.*)

This conceptually simple one-man one-vote approach has severe problems in the land use planning context on several grounds. How are the alternative resource use mix choices formulated and presented to the "voters"? How is the planned-for populace defined, located and canvassed? How are the desires of transient resource users (such as campers and hikers who do not belong to organized groups) to be counted, and how are they to be weighed against the needs and desires of permanent residents and users? (*C.F.S.*)

Major land use

U.S. Forest Service usage. A grouping of primary uses together into classes with similar characteristics—e.g., cropland, pasture, and forest. (*After U.S. Forest Serv. 1972B*)

Also see **Land use type**.

Management area

Range management usage. The total holdings under a single management. (*Amer. Soc. Range Manage. 1964*)

Management direction

U.S. Forest service usage. A statement of **goals** and a detailed specification of the ways and means for attaining them. (*W.W.*)

Management goal. See **Goal**.

Management objective. See **Objective**.

Management policy. See **Policy**.

Management program

Coastal zone management act usage. "Management program" includes, but is not limited to, a comprehensive statement in words, maps, illustrations, or other media of communication, prepared and adopted by the state setting forth **objectives**, **policies**, and **standards** to guide public and private uses of lands and waters in the coastal zone. (*After Coastal Zone Management Act 1972*)

Management situation

U.S. Forest Service usage. A section of the **planning area guide** which contains a comprehensive statement of the planning area resources, its history as it may influence planning, past and present uses, and a review of the publics directly concerned with the area. The significance of the information about the area as it relates to national **objectives** and program targets is also important as it will describe how that area is unique in its ability to contribute to the satisfaction of human needs. A projection of **program attainment targets** is also included. (*After U.S. Forest Serv., FSM 8222.2, Oct. 1973*)

This term is similar, but not identical to the term "environmental setting" as used in FSM 8412.2 item 3A.

Management unit

1. U.S. Forest Service usage. Under the "Multiple Use Planning" system used until 1972 they were subdivisions

of the "multiple use management zone" in the **ranger district multiple use plan**. It was the finest delineation of land areas.

Under the newly adopted U.S. Forest Service "Land Use Planning" system they are subdivisions of **planning units** which identify the area of land or water to which specific management decisions apply. All lands within a planning unit are included in one of the identified management units. (*U.S. Forest Serv., FSM 8226, Oct., 1973*)

2. Range management usage. A subdivision of a **management area**. (*Amer. Soc. Range Manage. 1964*)

Management zone

1. U.S. Forest Service usage. For planning purposes, areas of land with similar characteristics, whether they be social, economic, or environmental characteristics, may be delineated into management zones. Such a **stratification** is used for planning areas to help in delineating more precisely the particular area of land on which certain **coordinating criteria** apply. Three **management zones** are defined for forest service-wide use—**water influence**, **travel influence**, and **special management zones**. Other zones may also be designated by Regional Foresters. (*U.S. Forest Serv., FSM 8223, Oct., 1973*)

Where planning areas encompass lands in portions of two or more Forest Service Administrative Regions, the same zone name and description will be used throughout the **planning area**. The use of management zones is optional. However, if management zones are used, they will be applied uniformly throughout the planning area.

Map, operational

A precise, detailed, large-scale map, usually with small **contour intervals** but sometimes only planimetric (i.e., representing only the horizontal position of features), constructed for spe-

cific uses—such as administrative site development, road location, bridge sites, dam sites, campground development, ski areas, and geological area maps. (*U.S. Forest Serv. 1973*)

Map overlay (Overlay map)

1. A transparent sheet accompanying a map, on which information coloring, or symbols are entered so that when the overlay is placed on the map the effect is identical to having entered the overlay information on the map itself. By combining several overlays it becomes a simple matter to display a variety of data combinations and stratifications which would not be possible otherwise. (*E.C.T.*)

2. A map of an area to be superimposed on one or more maps of the same area. The purpose is to find the spatial distribution of data combinations, or more exactly the areas of joint occurrence and unsimilar occurrence. (*After Amidon 1972*)

3. A digital image (as in a computer) of areas as in definitions 1 and 2. (*After Amidon 1972*)

Map plan. See Paper plan.

Map, planimetric

A map representing only the horizontal position of features. (*U.S. Dep. Def. 1968*)

Contrast with a **topographic map** which shows both the horizontal and vertical position of features.

Marginal land

Land of questionable economic capabilities for a specific purpose. (*Amer. Soc. Range Manage. 1964*)

Market place

A hypothetical construct of economic theory representing the place all potential buyers and sellers of all goods and services come together, express their desires and offer their wares, through bargaining establish a price structure and production schedule, and complete their transactions. In standard

usage it refers to all locations where economic transactions occur treated as a single whole. (*E.C.T.*)

Market price. See **Market value.**

Market value (Market price)

1. A price at which both buyers and sellers are willing to do business; the market or current price. (*Webster 1963*)

2. "Market price": The price actually given in the current market dealings.

The price at which the supply and demand are equal. (*Webster 1963*)

Mass diagram

A graphical representation of cumulative quantities over time. Each point on the curve is the sum of all preceding quantities. (*After Soil Conserv. Soc. Amer. 1970*)

Mass instability (Slope stability)

An evaluation of the tendency for the materials on a slope (e.g., rocks, soil, snow) to move downhill as a large mass. (*C.F.S.*)

Also see **Landslide hazard**, **Snow avalanche hazard**.

Mass movement

Downslope, unit movement of a portion of the land's surface—i.e., a single landslide or the gradual simultaneous, downhill movement of the whole mass of loose earth material on a slope face. (*After Amer. Geol. Inst. 1962*)

Also see **Landslide**.

Mass-wasting

A general term for any of the variety of processes by which large masses of earth material are moved downslope by gravitational forces—either slowly or quickly. (*Amer. Geol. Inst. 1962*)

Also see **Landslide**.

Mast

Nuts, acorns, and similar products of hardwood species, which are consumed by animals. (*Amer. Soc. Range Manage. 1964*)

Master plan

1. City planning usage. A comprehensive, long-range plan intended to guide the growth and development of a city, town, or region, expressing official contemplations on the course its transportation, housing, and other community facilities should take, and making proposals for industrial settlement, commerce, population distribution, and other aspects of growth and development. (*Abrams 1971*)

2. Also see **Comprehensive plan**.

3. This term has been commonly used to describe or title any plan which is comprehensive or depicts or describes an ultimate state of development.

There is no unified agreement on its precise meaning or use in either theory or practice. The term is found in many books on planning, and appears in many planning ordinances and state laws—all of which seldom make more than a perfunctory or superficial attempt to define its use precisely. With respect to a suggested proper usage of "master plan", the California Planning Act (Calif. Gov. Code Title 7, Chap. 1, Art. 7, Sec. 65460) states that "Each commission or planning department shall prepare and the commission shall adopt a comprehensive, long-term general plan for the physical development of the city, county, area or region, and of any land outside its boundaries which in the commission's judgement bears relation to its planning. The plan may be referred to as the master or general plan, and shall be officially certified as the master or general plan upon its adoption by the planning commission and the legislative body." In this statement "master" never appears without the word "general". Thus "master" is made synonymous with "general". The statement also implies that adoption by an official body is a mandatory prerequisite for titling a plan "master plan". Thus plans not yet officially adopted should only use the term if it is qualified

by some phrase, such as "study for a . . ." or "proposed . . .".

The term "master" has connotations of grandiose schemes, an ultimate state and inflexible authority. This term has been so loosely, and often incorrectly or dishonestly, used that it has gained disfavor in the urban planning profession. They now prefer to instead use the term "general plan" (see **Comprehensive plan** definition 1) in the titles of their more comprehensive, long-range plans and proposals, because it has connotations of flexibility and thus more accurately reflects the nature of such plans. (*Marsh 1964*)

4. In the past, often defined and considered synonymous with comprehensive plan. More recently considered a component part or functional class of a comprehensive plan, for example, master plan for highways and thoroughfares, master plan for parks and recreation, etc. (*Soil Conserv. Soc. Amer. 1970*)

Material cycle. See **Biogeochemical cycle**.

Matrix

1. Mathematical usage. A rectangular array of rows and columns of real numbers. Matrices may be subjected to mathematical operations such as multiplication of one by another, addition of two or more, and others. Matrices may be manipulated in total in a manner similar to the algebraic manipulation of single numbers, but knowledge of special rules, called matrix algebra, is necessary for such manipulation. (*U.S. Gen. Account. Off. 1969*)

2. For land use planning's more traditional usage, see **Interaction matrix**.

Maximax

A method of choosing among alternatives by noting the attribute with the highest value for each alternative, and comparing these attributes across alternatives to choose the alternative with the maximum highest value. In order to

determine the attribute with the highest value for each alternative and follow this decision rule a very high degree of comparability between attributes within each alternative and among alternatives is needed. (*After Mac Crimmon 1968*)

Maximin

A method of choosing among alternatives by noting the attribute with the lowest value or quality standard least met for each alternative, and selecting the alternative with the most acceptable lowest valued attribute or standard. In order to determine the lowest valued attribute or worst met standard, and follow this decision rule a very high degree of comparability between attributes within each alternative and among alternatives is needed. (*After Mac Crimmon 1968*)

Maximum grazing capacity. See **Grazing capacity, maximum**

MBF (MBM).

Lumber or timber measurement term. One thousand board feet.

Meadow

1. Range management usage. A herb-land used primarily for hay production. (*Amer. Soc. Range Manage. 1964*)

2. Openings in forests and grasslands of exceptional productivity in arid regions, usually resulting from high water content of the soil, as in stream-side situations and areas having a **perched water table**. (*Amer. Soc. Range Manage. 1964*)

Median lethal dose (LD₅₀)

The amount of concentration of a toxic substance which will result in the death of 50 percent of a group of test organisms upon exposure (by ingestion, application, injection or in their surrounding environment) for a specified period of time. (*After Geckler, et al. 1963*)

Median tolerance limit (TL_m)

The concentration of some toxic substance at which just 50 percent of the test animals are able to survive for a specified period of exposure. (*Geckler, et al. 1963*)

Merit-weights

A system for evaluating differing uses by different sectors of the population. Espoused by Mack and Myers (1965) primarily as a method of comparing different outdoor recreation uses. The number of user-days in each activity by each section of the population is **weighted** prior to comparison by a value representing a societal social welfare function, and alternatives are compared based on these "merit-weighted" user days. (*E.C.T.*)

Mesic

1. Refers to environmental conditions that have medium moisture supplies rather than **Hygic** (wet) or **xeric** (dry) conditions. (*Hanson 1962*)

2. The nature of an organism requiring constant water availability. (*Dansereau 1957*)

Mesoclimate

The climate of small areas of the earth's surface which may not be representative of the general climate of the district area involved. It is rather indefinite and may include **topographic** or landscape features from a few acres to a few square miles, such as small valleys, "frost hollows", forest clearings, and open spaces in towns, all of which may have extremes of temperature differing by many degrees from those of adjacent areas. The mesoclimate is intermediate in scale between the **macroclimate** and the **microclimate**. (*Huschke 1959*)

Metamorphic rock. See **Rock, metamorphic.**

Metropolitan state economic area. See **State economic area, definition 2.**

Microclimate

1. The local climate of a given site or habitat varying in size from a tiny crevice to a large land area, but being usually characterized by considerable uniformity of climate over the site involved and relatively local as compared to its enveloping **macroclimate** from which it differs because of local climatic factors (such as elevation and exposure). (*Webster 1963*)

2. The fine climatic structure of the air space which extends from the very surface of the earth to a height where the effects of the immediate character of the underlying surface no longer can be distinguished from the general local climate (i.e., **mesoclimate** or **macroclimate**).

The microclimate varies with and in turn is superimposed upon the larger-scale conditions. While some rigid limits have been placed on the thickness of the layer concerned, it is more realistic to consider variable thicknesses—e.g., the microclimate of a putting green versus that of a redwood forest. Generally, four times the height of surface growth or structures defines the level where microclimatic overtones disappear.

Microclimate can be subdivided into as many different classes as there are types of underlying surface. With sufficient detail, this could be almost limitless. Currently, the most studied broad types are the "urban microclimate", affected by pavement, buildings, air pollution, dense inhabitation, etc. and the "vegetation microclimate", concerned with the complex nature of the air space occupied by vegetation, and its effects upon the vegetation. (*Huschke 1959, citing Geiger 1951*)

Microeconomics

Economic studies or statistics that consider particular individuals or single commodities; for example, the demand for wheat or for employment in the auto industry. (*Sloan 1961*)

Also see **Macroeconomics.**

Microrelief (Microtopography)

1. Ground surface irregularities which when compared from a fixed point of elevation between them display differences in elevation of not more than 10 feet nor less than 3 inches within a distance of 4 to 64 feet. (*Stone and Dugundji 1965*)

2. Minor differences in surface configuration of the land surface. (*Soil Conserv. Soc. Amer. 1970*)

Microtopography. See **Microrelief**.

Middle distance. See **Middleground**.

Middleground (middle distance)

1. Those portions of a scene, landscape, etc., which occur between the **foreground** and the **background**. (*Webster 1963*)

2. The portions of a view between 1/4 or 1/2 mile and three to five miles distant from the observer. The "middleground" portions of a view are especially critical because they tend to dominate the view. It is in this distance range that the emergence of shapes and patterns on the landscape can be clearly seen. Consequently the "Middleground" portions of a view often best show whether man-made changes rest easily or uneasily on the landscape. (*Litton 1968*)

Also see **Background** and **Foreground**.

Middle term planning. See **Mid-range planning**.

Mid-range planning (Middle term planning, Mid-term planning)

1. Planning that combines elements of both **long-range planning** and **short-range planning**. Generally, mid-range planning is designed for that period beyond the immediate actions of short-range planning, thus allowing a more general identification of long term objectives and goals, and yet within the time period where reasonably accurate predictions of the future with corresponding specific actions to be taken

are practical—typically between three and ten years in the future. Often, however, the planning process is merely divided into the short-range and long-range planning with a single dividing point, say five years in the future, and the mid-range classification is not used. (*E.C.T.*)

2. As used by the U.S. Water Resources Council in its **Principles and Standards**. Middle term refers to planning for periods up to 15 to 25 years in the future. (*U.S. Dep. Agric. 1974*)

Mineral

1. Mining laws usage. A substance is "mineral" under the general U.S. mining laws: (1) if it is scientifically recognized as such, (2) if it is classified commercially as such or (3) if it derives from the earth and possesses economic value and utility aside from the agricultural purposes of the surface itself. (*U.S. Forest Serv. 1958*)

The word "mineral" is not technical, either as having a special sense by commercial usage, or as having a scientific meaning different from the popular meaning. Mineral is a word of common speech and, as such, its interpretation is within the judicial knowledge and therefore a matter of law. (*Marvel vs. Merritt, 116 U.S. 11*)

2. Mineral rights usage. Every inorganic substance that can be extracted from the earth for profit, whether it be solid, liquid or gas.

This usage of the term "mineral" includes coal, petroleum and natural gas—even though these materials are not truly inorganic. (*Thrush 1968*)

3. Nontechnical usage. In a broad nontechnical sense the term "mineral" embraces all inorganic and organic substances that are extracted from the earth for use by man. (*Thrush 1968*)

Mineral, common variety

Earth materials which, although maybe having value for use in trade, manufacture, the sciences, or in the

mechanical or ornamental arts, do not possess a distinct, special economic value for such use over and above the normal uses of the general sum of such deposits. (*U.S. Forest Serv., FSM 2803.12, Jan 1959, citing 43 C.F.R. 185.121*)

For example, sand and gravel are frequently present in abundance in most areas and that makes them a “common variety mineral”.

Neither **mining claims** nor **mining claim patents** can be filed for “common variety mineral” deposits.

Mineral cycle. See **Biogeochemical cycle.**

Mineral entry

The filing of a **mining claim** for public land to obtain the right to any **minerals** it may contain. (*Thrush 1968*)

Mineral entry, withdrawals

U.S. Forest Service usage. The exclusion of **mining locations** and **mineral development work** on areas required for administrative sites by the Forest Service and other areas highly valued by the public. (*U.S. Forest Serv., FSM 2860.2, Mar. 1969*)

Mineral, excepted

Types of **minerals** which are exempted from the regulations in the general mining laws which authorize prospecting for and development of mineral resources on public lands.

The excepted minerals are: oil, gas, oil shale, coal, potassium, sodium and phosphates and in Louisiana and New Mexico, sulfur. Similarly excepted as to **mineral locations** made after 1955 are the **common variety minerals** sand, stone, gravel, pumice, pumicite or cinders. (*U.S. Forest Serv., FSM 2803.11, Jan. 1959*)

Also see **Mineral, leasable.**

Mineralization

The breakdown of organic compounds to their inorganic (i.e., **mineral**) forms—e.g., proteins to nitrates, phosphates, etc. (*Hanson 1962*)

Mineral, leasable

Types of minerals whose prospecting and development on public lands under permit or lease was authorized by the Mineral Leasing Act of February 25, 1920, as amended and supplemented (*41 Stat. 437; 30 U.S.C. 181-287*).

For example, coal, phosphate, sodium, potassium, oil, oil shale, gas and in some states sulfur. (*U.S. Forest Serv., FSM 2803.15, Jan. 1959*)

Also see **Mineral, excepted.**

Mineral, locatable

Precious or semi-precious **minerals** that are not considered to be **common variety minerals**—i.e., not such materials as sand or gravel.

Locatable mineral deposits can be claimed and the **mining claim patented**, thus converting it to private ownership. (*U.S. Forest Serv., FSM 2800R-8*)

Mineral location. See **Location.**

Mineral rights

The ownership of the **minerals** under a given surface, with the legal right to enter that area and mine and remove them—including the right to use as much of the land surface as may be reasonably necessary for the conduct of mining operations.

“Mineral rights” may be separated from the “surface rights” ownership, but, if not separated by a distinct conveyance, are included in the latter. (*Thrush 1968*)

Also see **Mineral, definition 2.**

Mineral soil

A **soil** consisting predominantly of, and having its properties determined predominantly by inorganic matter.

Usually containing less than 20 percent organic matter but sometimes containing an organic surface layer up to 30 centimeters thick. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Organic soil.**

Mine tailings

1. The waste material remaining

after raw minerals or ore have been processed. (*After Grim and Hill 1974*)

2. Material separated as refuse or separately treated as inferior in quality or value.

The sand, gravel and cobbles which pass through sluices in **placer mining**.

Refuse material resulting from the washing, concentration or treatment of ground ore.

The residual after most of a valuable ore has been extracted. (*Thrush 1968*)

3. The mining waste from **open-pit mining** is termed "spoils" while "tailings" is usually used for the waste from hard rock mining. (*After Grim and Hill 1974*)

Mining, area strip. See **Mining, area surface**.

Mining, area surface (Area strip mining)

A type of **open-pit mining** or **strip mining** that is generally practiced on gently rolling to relatively flat terrain on relatively large tracts of land and is commonly found in the mid and far western United States. A trench is first cut through the **overburden** to expose the deposit of mineral or ore to be removed. The first cut is extended to the limits of the property or deposits. The overburden from the first cut is placed on unmined land adjacent to the cut. The mineral or ore is then removed. Once the first cut is completed, a second cut is made parallel to the first, and the overburden from the succeeding cuts is deposited in the cut just previously excavated. The final cut leaves an open trench equal in depth to the thickness of the overburden and the mineral bed removed, bounded on one side by the last spoil pile and on the other by the undisturbed **highwall**. The final cut may be up to a mile or more from the starting point, and the overburden from the cuts, unless graded or leveled, resembles a plowed field or the ridges of a gigantic washboard. (*Grim and Hill 1974*)

Also contrast with **Mining, contour surface**.

Mining, auger

A mining method often used by **surface mine** operators when the amount of material overlying the seam from which a mineral (or ore) is being extracted gets too thick to be removed economically. Large diameter (2 to 7 feet), closely spaced holes are drilled up to 200 feet into the seam using an auger type bit whose head breaks up the deposit and whose screwlike extensions carry the material back out of the bore hole and into the open.

Auger mining is usually associated with contour **strip mining**. It is a common practice used to recover additional tonnage after the coal to **overburden** ratio has become too small to render further contour strip mining economical. When the slope is too steep for **contour mining**, augering is often performed directly into the hillside from a narrow bench. Augers are also used to recover coal near the outcrop that could not be extracted safely by underground mining. (*After Thrush 1968 and Grim and Hill 1974*)

Mining claim (Claim)

1. That portion of the public mineral lands which a miner, for mining purposes, takes and holds in accordance with mining laws. (*Thrush 1968*)

2. The portion of mining ground held under the Federal and local laws by one claimant or association, by virtue of one **location** and record.

A **lode claim's** maximum size is 600 by 1500 feet and a **placer claim's** 600 by 1320 feet.

A "claim" is sometimes called a "location" but these terms may often mean different things—e.g., "mining claim" may refer to a parcel of land containing soil or rock which has value because of its chemical composition, while "location" is the act of appropriating such land according to certain established rules. (*Thrush 1968*)

3. That portion of the public mineral lands located (see **location**) and

held for mining purposes. (*U.S. Forest Serv., FSM 2811.1.F, Sept., 1958*)

Mining claim, patented

A mining claim to which a patent has been secured from the government by compliance with the laws relating to such claims.

The patent is a legal document which conveys the title to the ground (i.e., **ownership**) to the claim's owner. No further annual assessment work need be done, but property taxes must henceforth be paid. (*Thrush 1968*)

Mining claim, valid

A claim where there is an actual discovery of valuable minerals in quantities such that it would be profitable to mine. (*U.S. Forest Serv. Lolo Natl. Forest 1974B*)

Mining, contour surface (Contour strip mining)

A type of **strip mining** that is practiced in areas of hilly topography when the coal seam outcrops on or approaches the surface at approximately the same elevation along a hillside. The conventional method of mining consists of removing the overburden from the mineral seam, starting at the outcrop and proceeding around the hillside. The cut appears as a contour line, thus, the name. Overburden is cast down the hillside and stacked along the outer edge of the operating bench. After the uncovered seam is removed, successive cuts are made until the depth of the overburden becomes too great for economical recovery of the coal. Physical limitations of equipment reach, capacity, etc., may also determine the strippable limit or cut-off point for mining. Contour mining creates a shelf or bench on the side of the hill. On the inside it is bordered by the **highwall**, ranging in height from a few feet to more than 100 feet; and on the outer side the pit is bordered by a high ridge of spoil with a precipitous downslope that is subject to se-

vere erosion and landslides. (*Grim and Hill 1974*)

Also contrast with **Area surface mining**.

Mining debris, hot (Hot waste, Hot spoils, Hot tailings)

Refers to materials in the **overburden**, **mining refuse**, **mine tailings** or **mining spoils** piles that are highly acid producing or difficult to revegetate because of its acid nature. (*Grim and Hill 1974*)

Contrasts with **sweet waste** which is neutral or slightly alkaline.

Mining debris, sweet (Sweet waste, Sweet spoils, Sweet tailings)

Refers to materials in the **overburden**, **mining refuse**, **mine tailings** or **mining spoils** that are neutral or slightly alkaline and capable of supporting certain calcium-demanding plants. (*After Grim and Hill 1974*)

Contrasts with **hot waste** which is highly acid or difficult to revegetate because of its acid nature.

Mining hydraulic. See Mining, placer.

Mining, lode

The mining of a valuable mineral which occurs as a tabular deposit between definite, contrasting mineral or rock boundaries.

"Lode", as used by miners is nearly synonymous with the term "vein" or "ore body" as employed by geologists. A lode consists of several veins spaced closely enough together so that all of them, together with the intervening rock, can be mined as a unit.

The maximum size of an individual "lode claim" is 1500 by 600 feet. (*Thrush 1968*)

Mining, open cast. See Mining, open-pit.

Mining, open cut. See Mining, open-pit.

Mining, open-pit (opencut mining, open cast mining)

A form of mining operation which extracts minerals that occur near the

surface from an open excavation. Waste materials overlying the minerals are first removed and then the mineral materials are broken up and removed.

The mining of metal bearing ores by **surface mining** methods is commonly termed "open-pit mining" as distinguished from the **strip mining** of coal and the "quarrying" of other non-metallic materials such as limestone, building stone, etc. (*Thrush 1968*)

Mining, pit

1. **Surface mining** in which the material mined is removed from below the surrounding land surface. (*Thrush 1968*)

2. Any mine, quarry or excavation area worked by **open-pit mining** methods to obtain material of value. (*Thrush 1968*)

Mining, placer

The extraction of valuable heavy minerals from a placer deposit (a mass of sand, gravel or other similar alluvial material) by concentration in running water.

When water under pressure is employed to break down placer deposits placer mining is generally termed "hydraulic mining". (*Thrush 1968*)

Mining, pre-law strip

A term used to refer to **strip mining** operations conducted previous to the passage of a states' first mining reclamation act. (*Grim and Hill 1974*)

Mining reclamation. See Reclamation.

Mining refuse

The solid waste from a mineral preparation or refining plant. (*After Grim and Hill 1974*)

Mining spoils (Mining waste)

1. The **overburden** or nonore material removed in gaining access to the ore of mineral material in **surface mining**. (*Thrush 1968*)

2. Any dirt or rock which has been removed from its original location by

mining operations—surface or subsurface. (*After Thrush 1968*)

3. All overburden material removed, disturbed or displaced from over a mineral deposit by excavating equipment, blasting, augering or any other means. (*Grim and Hill 1974*)

4. Contrast with **mining refuse** which is the solid waste left by mineral processing operations. **Mine tailings** is also sometimes used in this latter sense. (*After Grim and Hill 1974*)

Mining, strip

1. Any operation in connection with prospecting for, excavating, or mining **minerals** which results in a large-scale surface or stream bottom disturbance from stripping, trenching, dredging, rim cutting or **open-pit digging**. (*U.S. Forest Serv., FSM 2840, Sept., 1958*)

2. The mining of coal by **surface mining** methods as distinguished from the mining of metalliferous ores by surface mining methods which is commonly designated as "open-pit mining". (*Thrush 1968*)

3. Refers to a type of surface mining that removes all the waste material from over a coal deposit in a series of rows (or strips), one cut at a time.

Strip mining methods employed to recover coal can be divided into two general types: **area mining** and **contour mining**. (*Grim and Hill 1974*)

Mining, surface (Strip mining, Open cast mining, Open-cut mining, Open-pit mining)

1. Surface mining is a very broad term and refers to any process of removing the earth, rock, and other strata in order to uncover the underlying mineral or fuel deposit. (*Grim and Hill 1974*)

2. The removal of solid, earth materials having value from surface excavations.

This type of mining is generally

done where the material overlying the materials being sought can be removed without too much expense.

Surface mining of metal bearing ore is commonly termed **open-pit mining** while the surface mining methods used for coal removal are commonly termed **strip mining**. (*Thrush 1968*)

3. Mining activity involving extensive land surface, and/or water body disturbance, including "strip mining", **placer mining**, mineral exploratory activities, etc. (*Sandpoint Zone Planning Team*)

ining waste. See **Mining spoils**.

minority groups

A term commonly limited to racial and ethnic minorities, principally blacks and Spanish-speaking, but the meaning is currently in flux, and, by extension, may be applied to other minorities—American Indians, Oriental Americans, Appalachians, women, the young, the old, homosexuals, the imprisoned, the mentally ill, drug addicts, alcoholics and rural migrants. (*O'Connell 1974*)

Miscellaneous land type

U.S. Soil Conservation Service usage. A mapping unit for areas of land that have little or no natural soil, or that are too nearly inaccessible for orderly examination, or that occur where, for other reasons, it is not feasible to classify the soil.

Examples are **alluvial land**, badlands, made land, marsh, mine dump, mine wash, river wash, rock land, rough broken land, rubble land, scoria land, swamp, urban land. (*Soil Conserv. Soc. Amer. 1970*)

Mission

A major, continuing problem or concern that **programs** are designed to address. Missions represent the basic reasons for the existence of an organization in a governmental agency and characterize an organization's role in solving problems.

For example, some of the 11 missions of the U.S. Department of Agriculture are to work on problems associated with (1) environmental improvement, and resource development and use, (2) rural development, (3) agricultural production efficiency, etc. (*After U.S. Dep. Agric. Off. Manage. Finance 1974*)

Mobility, social. See **Social mobility**.

Model

1. An idealized representation of reality for purposes of describing, analyzing or understanding the behavior of some aspect of it. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations. (*U.S. Forest Serv. 1972B*)

2. A representation of the relationships that define a situation under study. A model may be a set of mathematical equations, a computer program, or any other type of representation, ranging from verbal statements to physical objects. (*U.S. Gen. Account. Off. 1969*)

3. A simplified representation of an operation, containing only those aspects of primary importance to the problem under study. (*U.S. Forest Serv. 1972B*)

Model, deterministic

A **model** in which the variables take on only definite values; that is, a model that does not permit any risk as to the magnitude of the variables. For example, a set of simultaneous equations for which there is a unique solution is a deterministic model. (*U.S. Gen. Account. Off. 1969*)

Also see **Model, probabilistic**.

Modeling. See **Model**.

Model, probabilistic

1. A **model** in which each variable

may take on more than one value. Such models are sometimes called stochastic which means, literally, making a best guess. (*U.S. Gen. Account. Off.* 1969)

2. A model that makes allowances for randomness in one or more of the factors that determine the outputs of the model. (*U.S. Forest Serv.* 1972B)

3. Also see **Model, deterministic.**

Model, stochastic. See **Model, probabilistic.**

Modulation

In land use planning "modulation" is the modification of any aspect of a land use plan in order that it more nearly expresses the constituency's interpretation of the relevant goals and objectives.

By "modulation" each part of the plan is kept in proper measure or proportion relative to the whole.

"Modulation" is the regulation of the various controlling factors—i.e., natural environment, institutional control and public demands in such a way that the optimum proportion of public welfare may be obtained. (*Hills, Love and Lacate* 1970)

Mores, social. See **Social mores.**

Morphogenetic region. See **Region, morphogenetic.**

Morphologic. See **Physiographic.**

Morphological map

A morphological map represents the form of the surface of the land.

For example, a map of occurrence of various slope steepness categories is a morphological map.

If some other aspect or classification, or interpretation of the earth's surface is shown a map is, for example a surficial geology, a soils, a morphographic or a morphogenetic map—not a morphological map. A **countour map** is not a morphological map because it only portrays elevation relationships. (*After Savigear* 1965)

Morphological region. See **Region, morphological.**

Morphology

Within the subject matter of **geomorphology**, the meaning of "morphology" is restricted to studies of the surface form of the earth—without any reference to the processes responsible for those forms.

"Morphology" is not synonymous with "geomorphology." (*After Savigear* 1965)

Most probable number (MPN)

A statistical evaluation of degree of water pollution based on presence of coliform bacteria. It is not feasible to identify the exact concentration of coliform bacteria in a water sample. The MPN interprets test results in terms of results observed. (*Feth* 1973)

MPN. See **Most probable number.**

Muddling through. See **Incrementalism.**

Multidisciplinary team

1. A joint effort by two or more people having different scientific training and/or backgrounds all assigned responsibilities in the same activity or effort. Each specialist is assigned a portion of the problem and their individual solutions are combined to provide the complete solution. (*After U.S. Forest Serv.* 1972B)

2. A group of individuals with different training assembled to solve a problem or perform a task. The team is assembled out of recognition that no one scientific discipline is sufficiently broad to adequately solve the problem. The problem is broken into pieces and each specialist works on a portion of the problem. Their partial solutions are then linked together to provide the final solution. This is different from an **interdisciplinary team** which does not break the problem apart by disciplines, but instead works with frequent interaction so that each discipline may provide insights into any part of the prob-

lem and disciplines may combine to provide new solutions beyond the scope of any single discipline. (*E.C.T.*)

Also see **Interdisciplinary team**.

Multifunctional

A joint effort by two or more people, each person having a different functional or resource responsibility such as timber management, engineering, etc., but not necessarily different training or backgrounds. (*U.S. Forest Serv. 1972B*)

Multiple use

1. Three somewhat different ideas are involved: (1) different uses of adjacent subareas which together form a composite multiple-use area, (2) the alternation in time of different uses on the same area, and (3) more than one use of an area at one time.

In the first two ideas it is implicit that direct competition between uses is avoided by alternating them in space or in time. The third idea involves multiple use in the sense of simultaneous use of one space and must concern itself with **complementary** versus **conflicting activities**, **compatible** and **incompatible uses**.

Where spatially coincident uses are involved at a given time, conflicts between resource users will almost always occur and the concept of such forms of multiple use should be realistically interpreted as a **dominant use** with **secondary uses** integrated only insofar as they are compatible with the first. However where the idea of incompatibility relates to the economics of productivity maximization of single resource yields, management and multiple use can perhaps be validated in terms other than single-resource production efficiency. (*After Rowe and Mc Cormack 1968*)

2. Multiple use is also a modern social concept whereby the consumer public demands a variety of values from a resource in ways that, to the

single purpose resource user, may seem inefficient or economically ruinous. Under this concept the aim of resource use allocation is to maximize the national well-being, promoting general social and economic prosperity.

Social needs are not necessarily best served by maximizing the production of a single resource (or even by maximizing the production of several resources) but by that over-all mix of total national resource uses that brings the greatest social and economic benefits. (*After Rowe and Mc Cormack 1968*)

Multiple use management

Multiple Use-Sustained Yield Act usage. The management of all the various renewable surface resources of the national forests so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output. (*Multiple Use-Sustained Yield Act*)

Multiple use planning

U.S. Forest Service usage. The official planning system for the National Forests until replaced in 1972 by the "land use planning" system. Based primarily on subdivisions within National Forests, the principal document was the **ranger district multiple use plan**. Each National Forest was divided into

Ranger Districts, Management zones, and Management Units. (After U.S. Forest Serv., FSM 8226, Oct., 1973)

In general, planning based on the concepts of multiple use and multiple use management. "Multiple use planning" is a less complex precursor of land use planning.

Multiple Use-Sustained Yield Act (74 Stat. 215; 16 U.S.C. 528-531)

Authorizes and directs that the National Forests be managed under principles of multiple use for outdoor recreation, range, timber, watershed, and wildlife and fish purposes, and to produce a sustained yield of products and services, and for other purposes.

This Act does not affect the use or administration of the mineral resources of National Forest lands or the use or administration of Federal lands not within National Forests. (U.S. Forest Serv. 1974)

Multiplier (Weights)

1. General "land use planning" usage. The numerical value reflecting relative importance which is assigned to a resource yield or use-affecting factor when all values cannot be directly compared by existing techniques for quantitative conversion to one measurement scale. (C.F.S.)

Also see **Weighting**.

2. Econometric usage. Although in simplified analysis "multipliers" are often treated as constants, in more detailed analysis multipliers are given by functions based on levels of, and degrees of change in, some economic activity. "Multipliers", in economic theory, are functions relating a change in some total measure to a change in some component of the total (the derivative of the total with respect to the component). Knowing the "multi-

plier" and the amount of a small change in the component, a simple multiplication gives a prediction of the change in the total. This prediction will be accurate if the basic equilibrium equations used to derive the multiplier accurately describe the economic processes involved. (After Samuelson 1948)

For example, export base analysis is a type of multiplier analysis. Here, it is assumed that there is a simple, multiplicative relationship between the "export" sector of the economy and the total economic activity of the region (the derivative of the total with respect to the export sector is a constant). Levels of, and changes in, the total regional economic activity are assumed to be simple multiples of the levels of, and changes in, the economic activity in the export sector. (E.C.T.)

MU-SY. See **Multiple Use-Sustained Yield Act**.

Myth

Sociological usage. A story, rationale or explanation for the belief(s) of a culture, **subculture**, **life style** or other **social group**—e.g., the belief of some that the physically rugged experience of wilderness living is good for one's health and many of the other beliefs about man's relationship to nature.

Popular usage regards "myths" as fanciful fiction; but in sociological usages the term is not used in the sense of beliefs which have been shown to be incorrect. Sociological usage of that term with respect to a belief places emphasis on the critical point that the myth (rightly or wrongly) is or has been believed and therefore can be used to explain people's **attitudes**, **behavior**, **preferences**, etc. (After O'Connell 1974)

National Ambient Air Quality Standards

Standards which define the levels of air quality which the U.S. Environmental Protection Agency judges are necessary to provide an adequate margin of safety to protect the public health. (*Sesco, et al. 1973*)

National economic development

1. U.S. Water Resources Council (WRC) usage.

One of the two main objectives of planning for water and related land resources by Federal agencies whose activities involve planning and development of water resources, as contained in the Water Resources Council **Principles and Standards**.

"National economic development" reflects increases in the Nation's productive output, an output which is partly reflected in a national product and income accounting framework to measure the continuing flow of goods and services into direct consumption or investment.

In addition, national economic development is affected by beneficial and adverse **externalities** stemming from normal economic production and consumption, imperfect market conditions, and changes in productivity of resource inputs due to investment.

National economic development as defined in these procedures is only partially reflected in the gross national product (GNP) and national income accounting framework. (*U.S. Dep. of Agric. 1974*)

2. One of the four "required accounts" for categorizing, displaying, or "accounting" the beneficial and adverse effects of each alternative plan formulation for water and related land resources planning specified in the Water Resources Council's "Principles and Standards" and the U.S. Dept. of Agriculture's "Procedures" for adher-

ing to them. (*After U.S. Dep. of Agric. 1974*)

3. Also see **Principles and Standards**.

National economic effects

Effects of an action or inaction on dollar market transactions in the Nation as a whole. This includes both aggregation of microeconomic effects (individual product, industry or sector effects) and macroeconomic effects (money supply, inflation, total economic growth effects). (*E.C.T.*)

National Environmental Policy Act (P.L. 91-190; 83 Stat. 852; 42 U.S.C. 4321, 4331-4335, 4341-4347)

An act to declare a National policy which will encourage productive and enjoyable harmony between man and his environment, to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man, to enrich the understanding of the ecological systems and natural resources important to the Nation and to establish a Council on Environmental Quality (CEQ). (*U.S. Forest Serv. 1974*)

Also see **Environmental impact statement**.

National Forest land use plan. See **Forest land use plan**.

National Forest System

The National Forest System consists of units of Federally owned forest, range, and related lands throughout the United States and its territories, united into a nationally significant system dedicated to the long-term benefit for present and future generations. The National Forest System includes all National Forest lands reserved or withdrawn from the public domain of the United States, all National Forest lands acquired through

purchase, exchange, donation, or other means, the National Grasslands and land utilization projects administered under Title III of the Bankhead-Jones Farm Tenant Act (50 Stat. 525, 7 U.S.C. 1010-1012), and other lands, waters, or interests therein which are administered by the Forest Service or are designated for administration through the Forest Service as a part of the system. (*Forest and Rangeland Renewable Resources Planning Act of 1974*)

National Historic Landmark

The **Historic Sites Act of 1935** authorized designation of areas of major National historic and cultural significance as "National Historic Landmarks".

The "National Historic Landmark" program is administered by the U.S. National Park Service.

Designation as a "National Historic Landmark" makes management of the resource for its historic values the dominant objective.

The landowner or manager must request that a property be considered for "Landmark" designation. It will not be placed on the Register of Historic Landmarks without his involvement and concurrence in the decision. (*U.S. Forest Serv., FSM 2363, July 1973*)

National Historic Preservation Act of 1966 (80 Stat. 915)

The National Historic Preservation Act of 1966 declares a National policy of historic preservation (defined in the Act as "the protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, or culture"), including the encouragement of preservation on the state and private levels; directs the expansion of the **National Register of Historic Places** to include cultural resources of

state and local as well as National significance; authorizes matching Federal grants to states and the National Trust for Historic Preservation for acquisition and rehabilitation of National Register properties; establishes an Advisory Council on Historic Preservation; provides procedures in Section 106 for Federal agencies to follow in the event a proposal may affect a National Register property. (*U.S. Forest Serv., FSM 2361.01, Feb. 1974*)

National Land Use Policy Act. See Land Use Policy and Planning Assistance Act.

National Natural Landmark. See National Registry of Natural Landmarks.

National Register of Historic Places

A listing (maintained by the U.S. National Park Service) of areas which have been designated as being of historical significance. The Register includes places of local and state significance as well as those of value to the Nation as a whole.

The Register is a National inventory of our historical resources, providing an idea of the total size of this resource base.

The "National Register of Historic Places" is separate and distinct from the **National Historic Landmarks** program—though the latter are routinely entered in the Register to afford them the additional protection of the **National Historic Preservation Act of 1966** which is not given by the **Historic Sites Act of 1935**.

Federal funds may not be expended on any project which will affect any site or object listed on the Register without first affording the Advisory Council an opportunity to comment. (*U.S. Forest Serv., FSM 2363, July 1973*)

National Registry of Natural Landmarks

A register of areas possessing such exceptional values or qualities for illus-

trating or interpreting the natural heritage of our Nation that they are considered to be of National significance. To possess National significance such an area must be a true, accurate, essentially unspoiled example of nature.

The legislative authority for the Natural Landmarks Program stems from the **Historic Sites Act** of August 21, 1935 (49 Stat. 666, 16 U.S.C. 641). The "Register of National Natural Landmarks" was established in 1963 and later renamed in 1965 to the "National Registry of Natural Landmarks".

The Natural Landmark program does not have the protection features of Section 106 of the National Historic Preservation Act of 1966. Thus, designation of a National Natural Landmark presently constitutes only an agreement with the owner to preserve, insofar as possible, the significant natural values of the site or area. Administration and preservation of Natural Landmarks is solely the owners responsibility. The agreement may be terminated by either party upon notification of the other. (*U.S. Forest Serv., FSM 2363, July 1973 and June 1974*)

National Trails System Act (82 Stat. 919; 16 U.S.C. 1241-1249)

Institutes a national system of recreation and scenic trails. Designates the Appalachian Trail and the Pacific Crest Trail as the initial components of that system and prescribes the methods by which, and standards according to which, additional components may be added to the system. Additional trails should be established primarily near urban areas and secondarily within established, more remotely located scenic areas. (*After U.S. Forest Serv. 1974*)

Native grazing land. See **Grazing land, native.**

Native organism

Animals or plants which originated

in the area in which they are found—i.e., were not introduced and naturally occur in that area. (*Henderson, Henderson and Kenneth 1963*)

Also see **Endemic organism** and contrast with **Species, resident; Species, naturalized; Species, exotic; and Species, feral.**

Native pasture. See **Pasture, native.**

Native pasture land. See **Pasture, native.**

Native species. See **Native organism.**

Natural

Existing in, or formed by, nature; not artificial. (*Stamp 1961*)

Natural Area. See **Natural Area Preserve** and **Natural Area, Research.**

Natural Area Preserve (Natural Reserve, Natural Area, Research Natural Area)

1. An area which retains a natural or relatively natural condition. Within it, wild parks, sanctuaries, refuges or wilderness can be designated. To qualify as a Natural Area Preserve, a site should be under protection, usually by a nonprofit agency or a Government agency. (*U.S. Bur. Outdoor Recreation 1974*)

2. A physical and biological unit in as near a natural condition as possible which exemplifies typical or unique vegetation and associated biotic, soil, geologic and aquatic features. The unit is maintained in a natural condition by allowing physical and biological processes to operate, usually without direct human intervention. (*Buckman and Quintus 1972*)

3. Also frequently used as a synonym for **Natural Area, Research.**

Natural Area, Research (Nature Reserve, Natural Area Preserve)

1. An area set aside by a public or private agency specifically to preserve a representative sample of an ecological community, primarily for scientific and educational purposes.

Commercial exploitation is ordinarily not allowed and general public use is discouraged.

Where the vegetation in the Natural Area is not of a stable, climax type, management measures may be taken to keep it at its present state—i.e., prescribed burning or controlled grazing to conserve certain floral and/or faunal characteristics. (*Ford-Robertson 1971*)

2. U.S. Bureau of Land Management usage. Areas containing typical or unusual faunistic or floristic types, associations, or other biotic phenomena, or characteristic or outstanding geologic, pedologic (i.e., soil), or aquatic features or processes, and which have been established and maintained for the primary purpose of research and education on the ecology, successional trends and other aspects of the natural environment.

Research and study that is nondestructive and consistent with the purpose for which such an area has been established is encouraged. The general public may be excluded or restricted where necessary to protect studies or preserve these areas. (*After 43 C.F.R. 6225.0-5(A)*)

3. U.S. Forest Service usage. Designated areas representing as many as possible of the major, natural timber types or other plant communities in unmodified condition. Other forest or range conditions that have special or unique characteristics of scientific or educational interest, such as examples of grass or timber types near the limits of their environmental range, unique bog associations, or unusual combinations of flora may also be set aside. To whatever extent is feasible, animal life should also be present in unmodified condition.

As a general guide, these areas should show evidence of no major disturbance by man, such as timber cutting, for at least the past 50 years. On rare occasions, however, in a valuable

plant community that should be preserved, the most suitable area that approached these conditions should be selected.

Research Natural Areas should be large enough to provide essentially unmodified conditions in their interior portions—usually over 300 acres. Exceptions to the usual minimum of 300 acres should be limited to truly outstanding cases.

The criterion for management of these areas is for protection against unnatural encroachments. Logging activities and uncontrolled grazing by domestic livestock are not permitted.

Forest Service Experiment Station directors may authorize such management practices as are necessary to preserve some representation of the vegetation for which the Natural Area was originally created. Only tried and reliable techniques will be used and then only where the vegetative type would otherwise be lost without management.

Research on Natural Areas will be essentially nondestructive in nature. (*After U.S. Forest Serv., FSM 4063, Jan. and Mar. 1975*)

Also see **Natural Area Preserve**.

Natural capability. See **Capability**.

Natural carrying capacity. See **Carrying capacity, ecological**.

Natural erosion. See **Erosion, natural**.

Natural hazard (Environmental hazard)

1. Those elements in the physical environment, harmful to man and caused by forces extraneous to him. (*Burton and Kates 1964*)

2. Those elements in the physical environment, which men perceive as harmful and caused by extraneous forces. (*Sims and Baumann 1974; modification of Burton and Kates 1964*)

Natural hazard lands

Usage in the defeated 1973 bill for

a National **Land Use Policy and Planning Assistance Act**.

Areas where uncontrolled or incompatible development could unreasonably endanger life and property. These lands include flood plains and areas frequently subject to weather disasters, areas of unstable geological, ice, or snow formations, and areas with high seismic or volcanic activity.

This is one of the three types of **areas of critical environmental concern** specifically set forth in this bill. The others are **renewable resource lands** and **fragile or historic lands**. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Natural history resource

U.S. Forest Service usage. Natural phenomena which reference the development of the earth's surface and the evolution of life. Two interrelated categories of natural features are recognized. One, the geological category, results from forces and processes acting on the earth's surface to produce land forms and other nonliving entities. The other, the ecological category, involves living entities and processes between biological forms and their environments. (*U.S. Forest Serv., FSM 2362.05, June 1974*)

Naturalized species. See **Species, naturalized**.

Natural law. See **Law, natural**.

Natural Preserve. See **Natural Area Preserve** and **Natural Area, Research**.

Natural Region. See **Region, Natural**.

Natural Reserve. See **Natural Area Preserve** and **Natural Area, Research**.

Natural Resource

1. A feature of the natural environment that is of value in serving human needs. (*Irland 1974*)

2. Any feature of the natural environment about which choices must be made. It need not be possessable to

be an object of choice. (*Irland 1974*)

3. Capacities or materials supplied by nature. (*Webster 1963*)

4. In the narrow sense, natural resources are original aspects of nature untransformed by man, such as air, water, sunshine, wild animals or wild vegetation, which are able to spontaneously satisfy human wants.

In a wider sense the term "natural resources" also encompasses the substances, forces, conditions, relationships and other aspects of nature which are transformed by man and underlie, shape, affect or inhere in that complex mixture of natural and cultural landscapes which constitute the environment of modern man. (*Stamp 1961, citing Encyclopedia of the Social Sciences 1933*)

5. The term "natural resources" is identical with the formal economic concept of **land**. (*Stamp 1961, citing Sloan and Zurcher 1949*)

6. To be considered a natural resource, a material or an area must be useful, or of value, to a particular culture. It must also, by definition, be basic or primary, not a manufactured or processed product. (*U.S. Bur. Outdoor Recreation 1974*)

Natural resource district. See **Soil conservation district**.

Natural resource zoning. See **Zoning, natural resource**.

Natural vegetation

1. The vegetation native to an area prior to modification by man. (*Durrenberger 1973*)

2. Vegetation which is primarily due to nature rather than to man. (*Stamp 1961, citing Tansley 1939*)

3. Vegetation (condition and/or species composition) that has been but little changed by man. (*Stamp 1961, citing Unstead 1953*)

Ecological research has demonstrated that little of the existing vege-

tation is unmodified by man's activities either directly (i.e., burning or cutting) or indirectly (i.e., introduction of grazing animals or exotic plants). The current tendency is to call all vegetation not deliberately managed or controlled by farming activities "natural vegetation" or to use the term "semi-natural". (*Stamp 1961*)

Nature Preserve. See **Natural Area Preserve** and **Natural Area, Research.**

Nature Reserve. See **Natural Area Preserve** and **Natural Area, Research.**

Needs

The fundamental motivations and requirements of man, not to be confused with "wants" or "desires". (*After U.S. Forest Serv. 1971*)

The distinction between "needs" and "wants" becomes cloudy and subject to debate beyond the minimal levels of basics such as food, clothing, shelter, drinkable water, and breathable air. Items which most Americans would consider necessities of life may be useless extravagances to other cultures. Psychological studies have indicated that conditions which should have no effect on the body may be necessities for maintaining mental health, and therefore physical health and productivity. (*E.C.T.*)

Negative declaration. See **Negative declaration statement.**

Negative declaration statement (Negative declaration)

A statement finding that a proposed action does not constitute a major Federal, state or local agency action significantly affecting the quality of the human environment and therefore does not require an **environmental impact statement**. (*E.C.T.*)

Also see **Environmental analysis report.**

Negative easement. See **Easement, negative.**

Negative feedback. See **Feedback loop.**

Nekton

The whole group of aquatic animals that swim actively and may move long distances for feeding or breeding.

Those aquatic organisms that are carried passively by water currents or the wind are termed **plankton** and those that dwell on the bottom **benthos**. (*Southward 1965*)

Neoteric area

U.S. Forest Service usage. Sites and areas which have been designated by the Forest Service as containing outstanding examples of man's modern culture which will obviously become historic properties in the future. An example would be a present-day building designed by a very popular architect. (*U.S. Forest Serv., FSM 2361.23, June 1974*)

Areas of this type and all other **special interest areas** are identified and formally classified primarily because of their recreational values. (*W.W.*)

NEPA. See **National Environmental Policy Act.**

Net residential density. See **Residential density.**

New study area. See **Wilderness study area.**

New wilderness study area. See **Wilderness study area.**

Niche

1. "Habitat niche" or "spatial niche" usage. A place or position of life suitable for the capabilities or merits of an organism or qualities of a thing.

A **site** or **habitat** supplying the factors characteristically necessary for the successful existence of an organism or species. (*After Webster 1963*)

2. "Ecological niche" usage. The role of an organism in an ecological community, involving especially its way of life and its effect on the envi-

ronment—as through its relations to other biotic and abiotic factors. (*Webster 1963*)

The “ecological niche” of an organism consists of where it lives, what it does (how it transforms energy, behaves, responds to and modifies its physical and biotic environment), and how it is constrained by other species. The “ecological niche” can be subdivided into a “**trophic niche**” and a “**multidimensional or hypervolume niche**”. (1) “**Trophic niche**”. The feeding role or position of an organism in a biotic community—e.g., **producer, consumer, herbivore, carnivore, detritivore**, etc. (2) “**Multidimensional or hypervolume niche**”. An organism’s position in the environmental gradients, such as temperature, moisture, **PH**, soil and other conditions controlling existence. (*After Odum 1971*)

Nitrogen cycle

The sequence of biochemical changes undergone by nitrogen, wherein it is used by a living organism, liberated upon the death and decomposition of the organism and converted to its original state of oxidation. (*Soil Conserv. Soc. Amer. 1970*)

Noise

Sound that lacks agreeable quality, is noticeably loud, harsh or discordant. (*Sesco, et al. 1973*)

Noise pollution

1. The addition of energy in the form of sound to the environment beyond what would naturally occur or of a type which would not naturally occur. The degree of pollution is measured in terms of intensity, duration, frequency of occurrence, and sound frequency (wavelength or pitch). (*E.C.T.*)

2. Sound that unreasonably interferes with the enjoyment of life or property. (*Sesco, et al. 1973*)

Nonapparent easement. See **Easement, discontinuous.**

Nonconforming use. See **Use, nonconforming.**

Nonconsumptive quality

The quality of an area or resource for satisfying uses which do not alter the area or resource. (*E.C.T.*)

Also see **Nonconsumptive use.**

Nonconsumptive use

1. Those uses of resources that do not reduce the supply, such as many types of recreation. (*U.S. Forest Serv. 1972B*)

2. A use of an area or resource which does not alter the area or resource, and which the fact of one person partaking of this use does not reduce the quality for another user. (*E.C.T.*)

3. For example, for water some **consumptive uses** are irrigation and domestic and industrial use, while “**nonconsumptive uses**” would include direct power generation as well as boating, swimming, etc. (*E.M.G.*)

Noncontinuous easement. See **Easement, discontinuous.**

Non-Federal lands

Usage in the now dead, 1973 bill for a National Land Use Policy and Planning Assistance Act. All lands which are not **Federal lands** or **reservation and other tribal lands** and which are not held by the Federal government in trust for the benefits of Indians, Aleuts, and Eskimos. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Non-market good valuation

Assessing the value of a good or service which is not traded in the **market place** and has no **market value**. Because it is not bought and sold some other measure than price must be used in establishing the value. (*E.C.T.*)

Also see **Market value.**

Nonmetric scaling

A method of choosing among alter-

natives similar to multiple factor analysis and not based on measuring values of the attributes of alternatives. The decision makers are given pairs of hypothetical alternatives varying in only one attribute. By statistical analysis the decision makers' preferences between the pairs are combined to give an "ideal alternative" as an origin and a coordinate system for measuring variations from the "ideal". The actual alternatives are then measured against this internally derived scale, and the alternative with the smallest distance in the coordinate system from the "ideal" origin is selected. (*After Mac Crimmon 1968*)

Nonpersistent pesticide (Soft pesticides)

A pesticide whose harmful effects are of relatively short duration and, therefore, do not normally contaminate the environment for long periods after application. Phosphate-based pesticides such as Malathion and Parathion are examples of nonpersistent pesticides. (*Sesco, et al. 1973*)

Non-point pollution source. See Non-point source pollution.

Non-point source pollution (Non-point pollution source)

Pollution whose source is general rather than specific in location. It is widely used in reference to agricultural and related pollutants. (*Sesco, et al. 1973*)

For example, logging operations production of sediments, agricultural pesticide applications, automobile exhaust pollution, etc.

Also see **Point source pollution**.

Nonrenewable resources (Stock resource, Exhaustible resource)

1. "Stock" resources and "exhaustible" resources are grouped here because they are conceptually very similar—if not often identical to—"nonrenewable" resources. (*C.F.S.*)

2. Resources whose total physical

quantity does not increase significantly with time. Thus with the total initial supply being limited in quantity each use must diminish the total stock (Wantrup's stock resources category). (*After Ciriacy-Wantrup 1968*)

3. The concept of an "exhaustible" resource is only meaningful if employed in an economic sense. Long before a given resource is physically used up it may be "exhausted" in the sense that further utilization is indefinitely discontinued because the costs of producing any possible quantity of this resource are larger than the revenues that could be obtained from this quantity. (*After Ciriacy-Wantrup 1968*)

The economic concept of resource exhaustibility typically only applies to **commodity** type resources because biological, locational and amenity type resources can be physically (by extinction or site occupancy) or conceptually (alteration of primeval wilderness conditions) exhausted. (*C.F.S.*)

Nonselected inventoried roadless area. See Nonselected roadless area.

Nonselected roadless area

A roadless or undeveloped portion of a National Forest greater than 5000 acres (or smaller than 5000 acres but contiguous to designated wilderness or primitive areas) which after administrative review by the Forest Service has been deleted from consideration for inclusion in the wilderness area system. (*U.S. Forest Serv., FSM 8261.05, Apr. 1974*)

Also see **Roadless and undeveloped areas** and **Wilderness study areas**.

Non-use. For range management usage see **Use, Non-**.

Non-utilization. For range management usage see **Use, Non-**.

Norm

An ideal standard of conduct or ethical value binding upon the members of a group which serves to guide,

control or regulate proper and acceptable behavior. (*Webster 1963*)

Also see **Social norms**.

Normal erosion. See **Erosion, normal**.

Normative

Of, relating to, or dealing with **norms**—i.e., the ideal standards of conduct or ethical value that are binding upon the members of a group and serve to guide, control or regulate proper and acceptable behavior. (*After Webster 1963*)

Noxious species

Range management usage. An unde-

sirable plant species that is unwholesome to the range or animal. Not to be confused with species declared noxious by certain laws. (*Amer. Soc. Range Manage. 1964*)

NPS. National Park Service, U.S. Department of Interior.

Nutrient cycle. See **Biogeochemical cycle**.

Nutritive value

Range management usage. Relative capacity of a given forage to furnish nutrition for animals. In range management, the term is usually prefixed by high, low, or moderate. (*Amer. Soc. Range Manage. 1964*)

O

OBERS projections

National, regional, and subregional **demand schedule projections** produced by the Office of Business Economics and Economic Research Service (OBERS) under the direction of the Water Resources Council (WRC). These economic projections are available in the WRC "1972 OBERS projections", and represent the Council's current views as to probable rates of growth in population, the gross national product (GNP), employment, productivity, and other factors.

These national baseline projections are the best estimate of what can be expected to materialize if there are no policy or program changes of an unusual or unforeseen nature or magnitude in the factors which have been changing over time and which are expected to continue on course in the future. Of course, identifiable, long-term secular trends are implicitly incorporated into the projections. (*After U.S. Dep. of Agric. 1974*)

Objective (Plan objectives, Management objective, End result, Target)

1. A clear and specific statement of planned results to be achieved within a

stated time period. The results indicated in the statement of objectives are those which are designed to achieve the desired state or process represented by the **goal**. An objective is measurable and implies precise time phased steps to be taken and resources to be used which, together, represent the basis for defining and controlling the work to be done.

An objective must include four essential elements. (1) It must state the desired outcome—i.e., what is to be accomplished. (2) It must indicate the time period within which the expected outcome is to be achieved. (3) It must include measurement factors, such as quantity, quality or cost, so that the fact that the objective has been accomplished can be verified. (4) It must indicate who is responsible for achieving the indicated results. Desirable, but not absolutely essential, elements of objectives are a description of how it will be achieved and an indication of who will determine whether the result has been achieved. (*U.S.D.A. Off. Manage. Finance 1974*)

2. The specific, attainable ends toward which concentrated effort is directed.

When achieved, objectives represent significant and measurable progress toward the attainment of a broader, longer range "goal".

Characteristically, objectives are subordinate to "goals", are narrower and shorter range in nature, have a reasonable probability of attainment within specified time periods and resources, and are attained through measurable and quantifiable achievements. Expected results are defined in terms of milestones accomplished, services produced, or some other objective measure, even though the specific contribution toward achieving the building block objective may not be measurable. (*U.S. Forest Serv. 1972B*)

3. "Objectives" are more specific and quantifiable than "goals" because (1) they mainly apply to a smaller constituency, (2) They usually apply to a narrower field of welfare, and (3) they can be framed with greater detailed understanding of immediate needs. (*After Hills, Love and Lacate 1970*)

Also see **Target**.

Observer inferior

That visual relationship between viewer and viewed which exists when the location from which something is seen is below the level of that object or the dominant visual elements in the surrounding landscape.

From the "observer inferior" position, features in the **foreground** (i.e., up to about $\frac{1}{2}$ mile distant) are most likely to be of maximum visual importance and the **middleground** (i.e., $\frac{1}{2}$ to 3-5 miles) landscape is likely to contain the most distant visible elements. (*After Litton 1966*)

Observer normal

1. That visual relationship between viewer and viewed which exists when the location from which something is seen is at (or approximately at) the level of that object or the dominant visual elements in the surrounding

landscape. (*After Litton 1966*)

2. That viewing position (with respect to a feature or scene) in which a level line-of sight will generally coincide with the visually dominant elements of the landscape.

The "observer normal" viewing position generally concentrates visual attention on the solid or water elements of the landscape rather than on the sky. (*Litton 1968*)

Observer superior

That visual relationship between viewer and viewed which exists when the location from which something is seen is above the level of that object or the dominant visual elements in the surrounding landscape.

From the "observer superior" position, the maximum extent and expanse of view is expected to be visible with atmospheric conditions and earth curvature being ultimate distance limitations. (*Litton 1966*)

OMB requirements

Regulations and directives established by the U.S. Office of Management and Budget (OMB) which all Federal agencies are required to obey and include in their planning and management activities. (*E.C.T.*)

For an example see **Questionnaire**.

Omnivore

An organism that feeds on both animal and plant substances. (*Durrenberger 1973*)

Open cast mining. See **Mining, open-pit.**

Open-cut mining. See **Mining, open-pit.**

Open-pit mining. See **Mining, open-pit.**

Open range

All suitable range of an area upon which grazing is permitted. Also, ranges which have not been fenced into management units. (*Amer. Soc. Range Manage. 1964*)

Open space

1. Unbuilt or predominantly un-

built land serving the following purposes; (1) conservation of land and its resource features, (2) ecological protection, (3) park and recreation purposes, (4) historic and/or scenic purposes, (5) shaping and guiding urban form, (6) enhancement of community values and safety, (7) maintenance of options for the future. (*After Assoc. Bay Area Govs. 1970*)

2. Land and water areas which are retained in essentially undeveloped state on a permanent or semipermanent basis. (*U.S. Bur. Outdoor Recreation 1974*)

pen space zoning. See **Zoning, open space.**

perational map. See **Map, operational.**

perational planning. See **Ordinary planning** and **Project planning.**

perations research

1. The use of analytic methods adopted from mathematics for solving operational problems. Among the common scientific techniques used in operations research are mathematical programming, statistical theory, information theory, game theory, Monte Carlo methods, and queueing theory. (*U.S. Forest Serv. 1972B*)

2. The application of mathematical and logical techniques to certain business problems with the object of discovering a best possible course of action. The procedure followed is usually to express the problem in the form of a mathematical equation, the solution of which indicates the effectiveness of a given set of conditions. The method may involve a sampling process, the calculation of probabilities, **linear programming**, or some other such technique. The computations are frequently so involved or so lengthy as to require electronic data processing. Sometimes called "management science." (*Sloan 1961*)

Opinion

A time-bound judgment or speculation that fluctuates unpredictably. In contrast to **beliefs** (i.e., tenaciously held convictions) "opinions" express what we believe at a given moment. "Opinions" generally are short-run impressions or "guesses" about specific objects, ideas, issues, or events that are usually involved with aspects of public affairs. (*O'Connell 1974*)

Also contrast with **Belief** and **Attitude.**

Opportunity cost

The value of the benefits foregone or given up due to the effect of choosing another management alternative that either impacts existing outputs or shifts resources away from other activities so that they are no longer produced and their benefits are lost. (*Dyrland 1973*)

Optimum land use

That **feasible** use which in the opinion of the decision maker provides the greatest increment of public welfare. (*Hills, Love and Lucate 1970*)

Option value

The amount an individual would be willing to pay to preserve (or would have to be paid to get him to sell) his option to participate in some activity or to use some resource at some future time, whether or not he ever actually participates or uses the resource. (*After Cicchetti and Fisher 1973*)

Ordinal value

Numerical values assigned to a variable which represent a ranking only. The numerical values have meaning only when compared to one another. Because of this, mathematical operations performed on the values (means, modes, differences, etc.) will not necessarily be valid, and the results of such operations must be carefully interpreted. (*E.C.T.*)

Also see **Cardinal value.**

Ordinance

1. A local law or regulation enacted by a city council or other similar body under powers delegated to it by the state. (*Webster 1963*)

2. A authoritative decree or direction. (*Webster 1963*)

Ordinary planning (Operational planning)

Any type of planning which, accepting existing **social institutions** as givens, seeks to design optimal alternative strategies for attaining optimal alternative futures. (*H.J.V.*)

Organic soil

A soil that contains a high percentage (greater than 20 or 30 percent) of organic matter in the upper layers (where living roots are primarily found). (*Soil Conserv. Soc. Amer. 1970*)

Also see **Mineral soil**.

Orphan banks. See **Orphan lands**.

Orphan lands (Orphan banks)

Disturbed land surfaces resulting from **surface mining** that were inadequately reclaimed by the operator and for which that person no longer has any legally fixed responsibility.

Usually refers to lands surface mined previous to the passage of comprehensive mining reclamation laws. (*Grim and Hill 1974*)

Outdoor recreation. See **Recreation**, definition 3.

Outdoor recreation and wilderness system

U.S. Forest Service usage. This system provides outdoor recreation opportunities and wilderness experiences for the Nation. The system includes all activities necessary to (1) develop, protect, and administer the forest recreational, scenic, and wilderness resources of the National Forests so that they will meet their full share of the Nation's existing and anticipated needs for these resources consistent with other uses, (2) develop new knowledge to improve the effectiveness of pro-

viding and managing outdoor recreation opportunities and wilderness, and (3) provide technical assistance and advice to other public and private forest landowners in developing forest-based recreational opportunities.

This is one of the six "systems" established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act** of 1974. It has grouped its various programs into these six "systems", each of which incorporates all the activities concerned with developing and managing a specific resource. (*After U.S. Forest Serv. 1974A*)

The six "systems" are: **Land and water**, **Timber resource**, **Outdoor recreation and wilderness**, **Rangeland grazing**, **Wildlife and fish habitat**, and **Human and community development**

Output

A broad term for describing any result, product, or service that a process or activity actually produces. (*U.S. Forest Serv. 1972B*)

Output, induced

The indirect result of system activities. They are generally the **primary outputs** of another resource system. An example is a specific form of timber harvest (primary) that produces improved wildlife habitat (induced). (*U.S. Forest Serv. 1974A*)

Output, primary

The main goods, services, or environmental conditions of a resource system—the key indicator used to identify with meeting a goal.

For example, the production of **animal-unit-months** of forage for livestock or board feet of timber harvested. (*U.S. Forest Serv. 1974A*)

verburden

1. Mining usage. Material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, ores or coal, especially overlying those deposits that are mined from the surface by open cuts. (*Thrush 1968*)

overgrazing, local

Overgrazing in localized areas on a range, as, for example, near watering places. (*Amer. Soc. Range Manage. 1964*)

overland flow (Sheet flow)

The rain storm or snow melt runoff water which flows over the ground surface as a thin layer—as opposed to the channelized (concentrated) runoff which occurs in rills and gulleys. (*After Soil Conserv. Soc. Amer. 1970*)

“Overland flow” typically causes sheet erosion.

Overlay map. See Map overlay.

Overstocking

Range management usage. Placing a number of animals on a given area that will result in **overuse** at the end of the planned grazing period.

Not to be confused with **overgrazing** because an area may be overstocked for a short period, but the animals may be removed before the area

is overutilized. However, continued overstocking will lead to overgrazing. (*Amer. Soc. Range Manage. 1964*)

Overstory

That portion of the trees in a forest, with more than one roughly horizontal layer of foliage, which forms the upper or uppermost layer. (*After Ford-Robertson 1971*)

Overuse. See Use, over-.

Over-utilization. See Use, over-.

Ownership

The exclusive right to occupy, sell, bequeath or mortgage property. (*Abrams 1971*)

Also see **Ownership, fee simple**.

Ownership, fee simple (Fee simple absolute, Fee simple title)

Ownership that may last forever and may be inherited by all heirs of an individual owner. This term is usually used in the sense of “fee simple absolute” which refers to ownership that has no limitation, qualification, or condition affecting it and is the maximum possible ownership in real estate under the system of property rights founded on English common law. (*After Webster 1963*)

Ownership rights. See **Bundle of rights**.

P

palatability

Range management usage. The relish that an animal shows for a particular species, plant or plant part. (*Amer. Soc. Range Manage. 1964*)

The characteristics of plants that stimulate a selective grazing or browsing response by animals. “Palatability” is controlled by the plant factors of chemical composition, proportion of plant parts, growth stage, external form of plant parts; environmental factors such as **slope steepness**, wind, sun or shade; and the animal fac-

tors of instinct, learning, physiological state, individual behavioral pattern variations and animal sensory responses. (*H.F.H.*)

Also see **Selectivity**.

Paleontological area

U.S. Forest Service usage. Areas which have been designated by the Forest Service as containing significant remains (usually fossilized) of **flora** and **fauna** (nonhuman) of geologic time periods before the appearance of man.

Areas containing scientifically or educationally significant fossilized specimens of flora and fauna from previous geologic periods—e.g., coal swamp forests, dinosaurs, etc.

Vertebrate fossils of historic or scientific significance are considered to be “antiquities” by the Antiquities Act.

Extant plants and animals which are **relics** of the flora and fauna or other geologic time periods and are of historic or scientific significance are considered under **botanical areas** or **zoological areas**, respectively. (*After U.S. Forest Serv., FSM 2362.45, July 1973*)

Areas of this type and all other special interest areas are identified and formally classified primarily because of their recreational values. (*W.W.*)

Panoramic landscape. See **Landscape, panoramic.**

Paper plan (Map plan)

A term sometimes used to describe formal plan documents which consist mainly of a map on which land use regulation districts are indicated. While a “paper plan” is accompanied by such explanatory written information as is necessary to convey its meaning, the basic regulatory document is the map.

In contrast, plans whose basic regulatory document consists of a set of policies are sometimes called **policy plans**, whether accompanied or not by maps differentiating the **planning area** into districts where some specific policies apply while others do not. (*C.F.S.*)

Paradigm

A collection of the major assumptions, concepts, and propositions in a substantive area. Paradigms serve to orient research and theorizing in the area, and in this respect they resemble models.

The usefulness of paradigms derives from their providing a compact codifi-

cation of the central concepts and their interrelations. This codification encourages research and theorizing and may allow qualitative analysis to approach the precision of quantitative analysis. (*O’Connell 1974*)

Parent material

The unconsolidated, chemically weathered mineral or organic matter from which the upper layers (i.e., where living roots are primarily found) of soil develop. (*After Soil Conserv. Soc. Amer. 1970*)

Parent plan

U.S. Forest Service usage. A plan establishing the decision framework in which other plans are made.

For example, the **planning area guide** is the parent plan for individual National Forest land use plans, and the National Forest land use plans are parent plans for unit plans. (*U.S. Forest Serv. 1971*)

Parent rock

1. The original rocks from which sediments were derived to form later rocks. (*Amer. Geol. Inst. 1962*)

2. The rock from which the **parent materials** of soils are formed. (*Amer. Geol. Inst. 1962*)

Pareto optimum

In welfare economics, a concept that sets a condition necessary to maximize the economic wealth of a given society. The pareto optimum is said to have been achieved when it is impossible to make one person better off without making another (or others) worse off. (*After U.S. Gen. Account. Off. 1969*)

Part per million (PPM)

One part by weight of dissolved chemical, or suspended sediment, in 1 million parts by weights of water. (*Feth 1973*)

Pasture

1. An area devoted to the produc-

tion of **forage** (introduced or native) and harvested by grazing. (*Soil Conserv. Soc. Amer. 1970*)

2. Grass or other growing plants used as food by grazing animals. (*Amer. Soc. Range Manage. 1964*)

3. A grazing area enclosed and separated from other areas by a fence. (*Amer. Soc. Range Manage. 1964*)

Pasture, annual

A **pasture** consisting of introduced forage species planted for only one year or season's duration. (*After Amer. Soc. Range Manage. 1964*)

Contrast with **Pasture, permanent**.

Pastureland

1. Land used primarily for the production of adapted domesticated forage plants to be grazed by livestock. (*U.S. Soil Conserv. Serv. 1970*)

2. Land producing forage plants, principally introduced species, for animal consumption. Management practices usually include one or more treatments such as reseeding, renovating, mowing, liming, or fertilizing. **Native pasture** that because of location or soil limitation is treated like **rangeland** is included in this category. (*U.S. Dep. Agric. 1967*)

Pastureland, native. See **Pasture, native**.

Pasture management

The application of practices to keep pasture plants growing actively over as long a period as possible so that they will provide palatable feed of high nutritive value; to encourage the growth of desirable grasses and legumes while crowding out weeds, brush, and inferior grasses. (*Soil Conserv. Soc. Amer. 1970*)

Pasture, native (Native pasture land)

Land used for grazing on which the climax (natural potential) plant community is forest but which is used and managed primarily to produce native or naturalized plants for forage. Includes cutover forest land, pasture-

land, or cropland originally cleared from forest and managed for native or naturalized forage plants. (*U.S. Soil Conserv. Serv. 1970*)

Pasture, permanent

A **pasture** consisting mainly of introduced perennial plants which are permitted to remain for a number of years. (*Amer. Soc. Range Manage. 1964*)

Contrast with **Pasture, annual**.

Pasture, rotation

1. A pasture of introduced perennial and/or self-seeding annual species, comprising a unit in a crop rotation of 5 years duration or less. (*Amer. Soc. Range Manage. 1964*)

2. May also refer to a pasture within a **rotation-grazing, deferred-rotation grazing, or rest-rotation grazing system**. (*Amer. Soc. Range Manage. 1964*)

Patch cutting

1. A **clearcutting system** variation in which the logging operation removes all merchantable timber in patches of about 40 to 200 acres, separated for as long as practicable (preferably until the regeneration is adequately shading the forest floor) by living forest, so as to both secure the optimum dispersal of seed and to avoid the high hazard of large continuous areas of logging debris. (*Ford-Robertson 1971*)

2. U.S. Forest Service usage. "Patch cuts" are logging operations of the size generally mapped for timber type and condition and for control, but which do not include the entire stand of which they are a part.

The minimum size will be 10 acres and the maximum size, 100 acres. (*After U.S. Forest Serv., FSM 2471R-3, date unknown*)

Patches are usually between 15 and 40 acres in size. (*After U.S. Forest Serv., FSM 2471.21R-5, Sept. 1971*)

Also see **Group cutting**, definition 2

for a comparison with similar logging approaches.

Patented mining claim. See **Mining claim**, patented.

Peak discharge

The maximum volume of flow attained at a given point in a stream during a runoff event. (*After Amer. Geol. Inst. 1962*)

Perched groundwater table. See **Water table**, perched.

Perched water table. See **Water table**, perched.

Percolation

The downward movement of water within a soil, especially the downward flow of water in saturated or nearly saturated soil.

Flow through a soil in contradistinction to the word **infiltration** which connotes flow through a soil. (*Soil Conserv. Soc. Amer. 1970*)

Perennial stream

Streams that flow throughout the year and from source to mouth. (*Amer. Geol. Inst. 1962*)

Also see **Ephemeral stream** and **Intermittent stream**.

Performance standard zoning. See **Zoning**, performance.

Performance zoning. See **Zoning**, performance.

Periodic allowable cut. See **Allowable cut**, definition 2.

Periodic allowable yield. See **Allowable cut**, definition 2.

Periodic cut. See **Allowable cut**, definition 2.

Periodic yield. See **Allowable cut**, definition 2.

Peripheral species. See **Species**, peripheral.

Permanent pasture

Artificial pasture consisting mainly

of perennial plants which are permitted to remain for a number of years. (*Amer. Soc. Range Manage. 1964*)

Permanent water

Range management usage. A watering place which supplies water at all times throughout the year or throughout a grazing season. (*Amer. Soc. Range Manage. 1964*)

Permeability

1. Capacity for transmitting water. It is measured by the rate at which water can move through soil in a given interval of time. (*Soil Conserv. Soc. Amer. 1970*)

2. The readiness with which water moves through the soil pores.

"Permeability" also implies movement into the soil and a "surface permeability" (i.e., an **infiltration rate** could be measured.

Quantitatively, "permeability" is the rate of readiness with which a soil transmits water under standard conditions. (*U.S. Forest Serv. 1961*)

3. The readiness with which soil or rock allows water, air, or plant roots to penetrate or pass through. (*After Webster 1963*)

Permissible cut. See **Allowable cut**, definition 2.

Permissible soil loss. See **Soil loss tolerance**.

Permissible yield. See **Allowable cut**, definition 2.

Persistent pesticides (Hard pesticides)

Pesticides composed of compounds that retain their toxicity for long periods of time after application such as DDT and many other chlorinated hydrocarbons. Such pesticides do not deteriorate quickly, work their way up the food chain through various animals and may accumulate in the fatty tissues of animals, including man, and remain there indefinitely. (*Sesco, et al. 1973*)

Personal distance. See **Individual distance.**

Personal space

Environmental psychology usage. An area with invisible boundaries surrounding a person's body into which intruders may not come. It is not necessarily spherical in shape, nor does it extend equally in all directions. An invasion of "personal space" is an intrusion into a person's self boundaries.

Individual distance and **personal space** interact to affect the distribution of persons. (*Sommer 1969*)

Also see **Individual distance.**

Persons at one time (PAOT)

Public recreational usage measurement term. The number of people in an area or using a facility at the same time. Generally used as "maximum PAOT" to indicate capacity of an area or facility to support peak usage loads. (*E.C.T.*)

Perspective

That which suggest the effects of distance upon the appearance of objects. (*Runes and Schrickel 1946*)

Perspective, aerial

Concerning the effects of distance from the viewer upon the color and distinctness of objects—especially as due to the transparency of the intervening air. Typically objects become bluer, greyer, edges less distinct, and there is less contrast of light and shade with increasing distance from the viewer. (*After Runes and Schrickel 1946*)

Perspective, linear

Pertaining to the effects of distance from a viewer upon the appearance of the size and form of objects. (*Runes and Schrickel 1946*)

PERT

Program Evaluation and Review Technique. See **Critical path method.**

Pesticide

A general term applied to a variety of chemical pest control measures, in-

cluding insecticides for insects, herbicides for plants, fungicides for fungi, and rodenticides for rodents. (*Sesco, et al. 1973*)

pH

A measure of the hydrogen-ion activity in solution, expressed on a scale 0 (highly acid) to 14 (highly basic); 7.0 pH is a neutral solution, neither acid nor basic. (*Feth 1973*)

Photomontage

1. A combination of several distinct photographic pictures so they often blend with or into each other to produce a composite picture which may or may not appear to be made up of separate pictures. (*Webster 1963*)

2. A composite picture or edited film in which contrasting shots or sequences are juxtaposed or blended for the purpose of suggesting a total idea or impression, or developing a theme. (*After Webster 1963*)

Phreatophyte

1. A type of plant that habitually obtains its water supply from the zone of groundwater saturation, either directly from within the ground water level or from the capillary fringe just above it. (*Durrenberger 1973*)

2. Plants which grow from ground water supplies. (*Marsh 1964*)

Physical carrying capacity. See **Carrying capacity, ecological definition 5.**

Physical life

That period of time that a facility exists, not necessarily in a useable condition or used. Often facilities are removed from active service and kept intact some years before they are junked or destroyed, or they may be just left in their service position but never used. (*Winfrey and Zellner 1971*)

Also see **Economic life.**

Physical planning

1. A form of urban land use planning which attempts to achieve a phys-

ically attractive urban **open space** environment by regulating the physical relationships of structures to their sites and surroundings—with such devices as set back requirements, building height controls, maximum lot coverage by structures and unnatural surfaces, etc. (C.F.S.)

The intent of such physical standards is to avoid the claustrophobic and ugly urban open space environments which came to characterize cities in the 1800's. Some feel that rigid application of these regulatory tools is responsible for much of the physical monotony in our present cities. (C.F.S.)

Physiographic (Morphologic)

1. Physiography is the description of the surface features of the earth, as bodies of air, water and land. (Stamp 1961, citing Powell 1895)

2. Physiographic refers to the surface features of the earth's solid crust and with the relations of air and water to it. (Stamp 1961, citing Salisbury 1907)

3. In the United States the term "physiographic" is sometimes used as equivalent to geomorphologic. However, **geomorphology** is definitely limited to the study of landform genesis. Whereas "physiography" may be only descriptive, "geomorphology" must be interpretive of the origins of land surface forms. (Stamp 1961, citing Fenneman 1938 after Stamp 1961)

In the United States "physiographic" is used in the same sense as the British usage of "morphologic"—i.e., relating to the form of land surfaces. (After Stamp 1961)

Physiographic climax. See **Climax community**, definition 3.

Physiographic determinism

A theory that the natural elements of an environment should be respected in planning and given priority consideration in arriving at **policy** determina-

tions. For example, "nature" should have priority in the planning the "aquifers" and wetlands, and the rest of nature's assets should be preserved in any development plan. (After Abrams 1971)

Physiographic determinism is essentially equivalent to **ecologic determinism** and **biophysical determinism**. However in its true meaning physiographic only refers to the nonliving elements of an environment while "physiographic determinism" is intended to encompass the living elements as well. (C.F.S.)

Physiographic production

Referring to those controls over the amount of occurring or potential **biotic productivity** which are due to **abiotic** environmental factors (such as **regional climate**, geologic materials, **slope orientation**, elevation, etc.). (C.F.S.)

Physiographic province. See **Region**, **physiographic**.

Physiographic region. See **Region**, **physiographic**.

Physiographic site class

G.A. Hills land classification usage. Units created by isolating areas within the **landtypes** on the basis of local climate considerations—such as slope orientation. (After Belknap and Furtado 1967)

Subdivisions of a "landtype" based on local climate variations in air temperature and humidity. Variation in plant communities is used as the principal indicator of climate variation. (After Belknap and Furtado 1967)

The third largest unit in Hills' land classification system. The various levels, in order of decreasing size, are **Site region**, **Landtype**, **Physiographic site class**, **Physiographic site type** and **Physiographic site phase**.

Physiographic site phase

G.A. Hills land classification usage

If specific land use activity requirements cannot be determined on the basis of the information contained in **physiographic site types**, a "physiographic site phase" is added to the hierarchy to isolate the other needed significant qualities. (*After Belknap and Furtado 1967*)

A "site phase" is created by adding information on the use requirements (e.g., beach slope and width, water depth) to the map of "physiographic site types". (*After Belknap and Furtado 1967*)

Further subdivision of "site types" to indicate site requirements for specific activities. (*After Belknap and Furtado 1967*)

The various levels in Hills' land classification system, in order of decreasing size, are **Site region**, **Landtype**, **Physiographic site class**, **Physiographic site type** and **Physiographic site phase**.

Physiographic site type (Landscape type, Facies)

G.A. Hills land classification usage. The smallest unit with any homogeneity in landscape features. (*After Belknap and Furtado 1967*)

The units delineated by differentiation of micro-landform variations (ex. ridge tops, valley bottoms, toeslopes, etc.) within a **physiographic site class**. (*After Belknap and Furtado 1967*)

A subdivision of the physiographic site class based on local variations in soil moisture and depth.

A physiographic site type can vary from 5 to 100 acres.

The site type is the basic unit of plant ecology according to Hills. According to the natural controls of plant succession and the human controls of crop production, a variety of ecosystems may develop on each physiographic site type. Crop production is defined broadly to include such uses as corn, houses, or a recreational activity. (*After Belknap and Furtado 1967*)

Generally the smallest unit in Hills'

land classification system. The various levels, in order of decreasing size, are **site region**, **landtype**, **Physiographic site class**, **Physiographic site type** and **Physiographic site phase**.

Phytoplankton. See **Plankton**.

Pit mining. See **Mining**, open-pit.

Pitting

Range management usage. Making shallow pits or basins of adequate capacity and distribution on range to speed range improvement by retaining water from rainfall and snowmelt and by reducing competition to desirable species from a dense stand of less desirable vegetation. (*Amer. Soc. Range Manage. 1964*)

Placer claim

A mining claim located upon a mass of gravel, sand, or similar material (resulting from weathering, erosion and/or stream deposition) containing particles of gold, platinum, tin or other valuable minerals and whose valuable mineral contents are extracted by concentration in running water.

The maximum size of an individual "placer claim" is 600 by 1320 feet (10 acres). (*Thrush 1968*)

Placer mining. See **Mining**, placer.

Plan

1. A formalized statement of **goals**, **objectives**, and **policies**. (*U.S. Forest Serv. 1971*)

2. An assemblage of management directions. (*U.S. Forest Serv. 1971*)

3. A predetermined course of action. (*U.S. Forest Serv. 1971*)

4. A plan is an ordered decision or set of decisions on the ways in which to achieve certain objectives.

A plan is not an end in itself. It is a means to an end, and the end is more important than the means. (*Allen and Sharpe 1960*)

5. Statements in words and graphics of the findings, conclusions, pro-

posals and recommendations of the planning process. When adopted, "plans" become public policies and programs.

"Plans" are working instruments—guides for administration, but not end products. As such, plans are never completed. Plans are subject to change as policies change due to unfolding events, such as changing standards of life style, environmental factors, and advancing technology. (*U.S. Civil Serv. Comm.*, 1973)

Plan controls

Any of the various legal and administrative methods which are available for implementing a land use plan's goals, objectives, or policies. (*C.F.S.*)

"Plan controls" include such devices as **ordinances**, **zoning**, use permit and hearing procedures, design criteria, performance standards or any other formal means or procedure for attaining a land use plan's goals, objectives or policies. (*C.F.S.*)

Plan element

1. U.S. Forest Service usage. The major land use planning elements of the U.S. Forest Service are: legal requirements and authorities, national and regional objectives and **targets**, **management situation**, **basic assumptions**, data collection, land **capability**, alternative considerations, plan selection, **functional planning** and documentation. (*U.S. Forest Serv., FSM 8213, Oct., 1973*)

2. A discrete topic area or issue of concern in an overall plan—e.g., housing, open space, recreation, transportation. (*C.F.S.*)

Plan goals. See **Goal**.

Planimetric map. See **Map**, **planimetric**.

Plankton

The small (usually less than 2mm long) floating or drifting life forms in water bodies, plankton includes both plants (phytoplankton) and animals

(zooplankton) that are carried passively in the water currents. Those that can swim do so to change or adjust their depth in the water, not to move from place to place.

Plankton is one of the 3 main divisions of aquatic life with the other being "nekton" (the animals that swim actively and may move long distances for feeding or breeding) and the "benthos" (organisms which crawl about on the bottom, or burrow into the bottom or grow attached to the bottom). (*Southward 1965*)

Planned grazing system

A system of grazing in which two or more grazing units are alternately rested from grazing in a planned sequence over a period of years. The rest may be throughout the year or during the growing season of the key species (*D.E.H. and B.W.*)

Planned unit development. See **Cluster development**.

Planned unit development zoning. See **Zoning**, **cluster**.

Planner

1. Anyone who plans—for example, a city planner, economic planner, public health planner, social planner or landscape planner. (*Abrams 1973*)

2. One whose profession consists of identifying community needs, resources and problems and assisting citizens in making decisions on **goals**, **policies**, **priorities**, **plans**, **programs** and methods of implementation designed to create a physical, economic and social environment in which the human activities desired by the members of the community may flourish. (*U.S. Civil Serv. Comm.*, 1973)

Planning

1. The act of deciding, in advance what to do. A dynamic effort to use decisions to guide future actions and decisions.

A means of solving future problems.

by intent. One step in the process of guiding the future. (*U.S. Forest Serv. 1971*)

2. The determination of the **objectives** or goals of an enterprise and the selection, through a systematic consideration of alternatives, of the **policies, programs** and procedures for achieving them. (*U.S. Forest Serv. 1972B*)

3. Colloquial context—designing the future organization and relationship of parts. (*Friedman 1963*)

4. Professional context—the process of finding alternative solutions to a problem. A way of thinking about and coming up with solutions for future problems. (*Friedman 1963*)

5. A process oriented predominantly toward the future and deeply concerned with the relation of goals to collective decisions in policy and program. (*Friedman 1963*)

6. A process of conflict resolution (usually future) by designing optimum relationships between components without attempting to favor or eliminate any party in the (future) conflict. (*H.J.V.*)

7. The attainment or the effort to attain, some future objective or objectives by a rational determination in the present of the requisite resources, personnel, and procedures needed to achieve that objective or those goals. (*Mc Closkey 1971*)

8. A continuous process through which some **planning agent** identifies goals, designs alternative resource-use programs, selects and activates a program, and analyzes its consequences for the purpose of determining whether the goals are being achieved. (*H.J.V.*)

9. A method of public decision-making which emphasizes explicit goal-choice and rational goals-means determination, so that decisions can be based on the goals people are seeking and on the most effective programs to achieve them. (*Gans 1968*)

10. The planning process can be conceptually divided into five phases: (1) identification of opportunities, problems and issues; (2) formulation of policies and objectives; (3) data collection, analysis and interpretation; (4) plan formulation; and, (5) plan implementation. In practice, these are not discrete steps and the sequence may vary. Objectives are refined as the process proceeds. Feedback among the phases is continuous. Work on plan formulation often indicates the need for additional information which may alter the conception of objectives and problems. In addition, experiences with implementation may result in plan modification or the need for additional information. Each phase of the process is strongly interconnected with all the others in a monitoring **feedback loop**. Citizen participation, public input, and reaction are a key part of every phase in the planning process. (*Calif. Council Intergov. Relat. 1973*)

11. The process of preparing a set of alternative courses for decisions in establishing the best action to insure the future availability and development of adequate resources, facilities, and services required to support human activities. (*U.S. Civil Serv. Comm. 1973*)

Planning agent

The person(s) or organization actually doing the planning. A “planning agent” may be a natural person (an individual householder or entrepreneur), a family, a legal person (a corporation, a trade association), or various levels of government (Federal, state, county, public district). (*H.J.V.*)

Planning, anticipatory

Any planning approach which operates by attempting to foresee potential issues and develop solutions to them before they become real, overt problems. (*C.F.S.*)

Planning area

1. U.S. Forest Service usage. A specifically identified geographic area containing social and physical resources and land characteristics of a generally similar nature.

The reason for identifying planning areas is that general similarities in physical characteristics, resources, economics, and social needs should give rise to similar management opportunities, and constraints. Therefore, all planning efforts, irrespective of administration or government boundaries, should be coordinated.

A variety of considerations may interact to determine the size and boundaries of a planning area; topography, vegetation or broad habitat type, climate, history of land use, populations—human and animal, economy and the relationship of these and other elements to each other will affect the definition of a planning area. These areas may, and will likely, cross such administrative boundaries as Forest Service Regions, National Forests, and Ranger Districts. A planning area should be of sufficient size to provide for flexibility in patterns of land development and use of resources. State and multicounty planning districts, and the integrity of counties, should be strong considerations in the establishment of planning area boundaries. Commonality of boundaries will aid in cooperative planning and data exchange. The area should permit a maximum of agencies or governments to contribute and receive resource data and relate demand allocations with the highest degree of compatibility practical.

Planning area level considerations are basic for all Forest Service land and resource management programs in that area. The Regional Foresters in such planning areas provide the management direction for each area by coordinating the managers having

Forest Service land management responsibilities (National Forest Service State and Private Forests; and Research, as appropriate). They also maintain coordination between Forest Service and other government agencies (State and Federal), and attempt to make coordinated demand projections for the resources located within the land area with specific allocation to the National Forest lands. (*U.S. Forest Serv., FSM 8221, Oct., 1973*)

2. U.S. Forest Service usage. The geographical area to which a **planning area guide** applies.

3. U.S. Forest Service usage. The largest Forest Service land use planning subdivision.

“Planning areas” are delineated by use of county boundaries in the California Region.

Planning area guide (Guide, Area guide)

1. U.S. Forest Service usage.

A Forest Service document which specifies the peculiarities of the **planning area** as compared to other areas and provides an interpretation of the significance to management of these peculiarities.

The objective of the guide is to provide broad land use direction to be followed by all Forest Service administrative units with land management responsibilities within the planning area.

The planning area guide should provide **goals** and **targets** reflecting the National Forest's share of all forest objectives and outputs for the planning area, including, and in relation to State and private lands. (*U.S. Forest Serv., FSM 8222.1, Oct., 1973*)

A document that provides broad management direction for all National Forest System land planning, management, development, use, and protection activities within the planning area. A separate planning area guide is developed for each planning area. A “plan-

ning area guide" is frequently referred to merely as the "guide" or "area guide".

Planning horizon

1. The time period (fixed by the planner) which will be considered in the planning process. It is assumed to span all activities covered in the plan and all future conditions and effects of alternative actions which would influence the planning decisions. (*E.C.T.*)

2. U.S. Forest Service usage. The furthest point in time for which management systems are specified in a management program for a planning unit.

For example, in the 1970 timber review, the "planning horizon" was 2020. (*U.S. Forest Serv. 1972B*)

Planning level

Referring to the scale of a planning effort—usually denoted by the size of the project or the governmental level at which the planning is being done, e.g., site or project planning, municipal planning, county planning, metropolitan regional planning, state planning, interstate regional planning, national planning, etc. (*C.F.S.*)

Planning process. See Planning definition 10.

Planning-Programming-Budgeting System (PPBS)

A planning and decision-making tool that attempts to organize information and analysis so that the consequences of alternative policies are clearly revealed and fully comparable. Under PPBS, ordered instituted in each Cabinet agency by President Johnson in 1966, programs having the same purpose are grouped together under the same category and compared to see which represents the best use of the government's money. PPBS endeavors to display the allocation of resources in terms of the function; to gather hard, quantitative information on the actual results of programs; and

to analyze the cost of the various efforts to achieve similar ends and rank them in terms of their effectiveness per dollar. (*Abrams 1971*)

Planning unit

1. U.S. Forest Service usage. National Forests (including lands within and contiguous to National Forests) are subdivided into planning units. These units are geographic areas of land, varying in size, that are characterized by particular patterns of topography, climate, and land use. A unit may occur as one major drainage, several separate drainages, or portions of drainages.

Planning units are described as specific, identified and delineated land areas. They are large enough to encompass most of the meaningful or significant relationships within a drainage or series of drainages. Topographic features are logical places for planning unit boundaries because of the need to be able to identify boundaries on maps and photographs, and on the ground.

A number of factors influence the boundaries, size, and layout of planning units, among which are: (1) intensity of planning expected; (2) the resources available for doing planning, such as people and time; (3) presence or absence of particularly unique features; (4) perceived complexity or homogeneity of the land features; (5) public involvement inputs; and (6) planning team judgment.

In defining these units, the objective is to preserve as much uniformity as possible in relationships significant to land management. Such factors as existing transportation systems, population influences, current land use, topography, soils, industrial dependency, ownership, and public feelings are considered in establishing the boundaries for planning units. No two planning units are exactly equivalent in the factors which influence the boundaries of the planning unit.

The purpose of planning units is to provide a focus for planning activities in a small enough area to be workable and large enough to enable a planning team to envision or predict the cause-and-effect relationships of management alternatives. (*U.S. Forest Serv., FSM 8226, Oct. 1973*)

2. U.S. Forest Service usage. That geographical area of land and water, smaller than a Forest Service **planning area** to which a forest service **unit plan** applies.

No size limits are arbitrarily established for planning units. Planning unit boundaries may cross both planning area and **administrative unit** boundaries.

The "planning unit" will be the only area for which a **site specific plan** will be developed. Planning for the other two types of areas in the U.S. Forest Service land use planning system, the planning area and the national forest, concentrate more on general **assumptions, goals, policies, targets**, national and regional conditions, etc, to build the framework within which the "unit planning" will occur. (*After Rupp 1974*)

Plan objective. See **Objective**.

Plan selection

1. U.S. Forest Service usage. Subjected to the planning process, it is essentially a choice governed by a reasonable and rational perception of how the available resources can be most efficiently managed to achieve optimum multibenefits for the American people. The process includes full consideration of the priorities and preferences expressed by the public at all levels to be affected by the plan. (*U.S. Forest Serv., FSM 8213, Oct. 1973*)

2. The selection of one plan from a set of alternative plans. (*E.C.T.*)

Plant association. See **Plant community**.

Plant community

1. Any aggregation of plants. (*Hanson and Churchill 1961*)

2. A group of **stands** (i.e., a particular aggregation of plants having a high degree of uniformity in composition and structure and occupying an area of essentially uniform environment) that are similar in species composition and structure and occupy similar habitats (*Hanson and Churchill 1961*)

3. Plant species tend to be grouped in different combinations forming more or less definite "communities" Each of these communities is characterized by certain species which are inconspicuous or unrepresented in other communities, and wherever areas of equivalent environment are encountered, whether continuous or detached, essentially the same plant assemblage reappears. In other words the individuals of each species are not scattered at random, but are distributed in a pattern over the landscape (*Daubenmire 1968*)

Also see **Biotic community**.

Plant cover type. See **Cover type**.

Plant retrogression

The process of vegetational deterioration whereby the same area becomes successively occupied by different **plant communities** of lower ecological order in **succession**. (*Amer. Soc. Range Manage. 1964*)

Plant succession. See **Succession**.

Plat

A diagram drawn to scale and showing essential data pertaining to boundaries and subdivisions of a tract of land, as determined by survey or drawing to scale.

The primary purpose of a plat is to show boundary survey and ownership information rather than map information. (*U.S. Forest Serv., FSM 7140.5 June 1973*)

uralism

A description of society that contends that political power is distributed among a variety of groups and **institutions**. Pluralist theory argues that political resources—wealth, education, prestige, skill, votes—are divided and that no group has a monopoly over all resources.

In contrast, elitist theories of power argue that small groups of individuals rule a country in their own economic interest. Pluralists agree that only small numbers of citizens participate directly in decision-making, but they argue that these elites compete for economic rewards, differ on policy, are open for others to join, and are indirectly influenced by voters. “Elitists” contend that members of the ruling power elite share a procapitalist ideology, are unified by a similar upper-class background, and are linked by institutional and personal ties. (O’Connell 1974)

pluralistic society (Cultural pluralism)

A society in which there are widely differing and often conflicting points of view as to how the access to or use of a particular resource (or resources in general) should be allocated. The United States is most often cited as the prime example of a pluralistic society. (C.F.S.)

utonic rock. See **Rock**, igneous.

oint pollution source. See **Point source pollution**.

oint source pollution (Point pollution source)

Pollution whose source is specific rather than general in location. For example, particulate matter emanating from a specific smoke stack is point source pollution. (Sesco, et al. 1973)

Also see **Non-point source pollution**.

olice power

A state’s inherent and plenary pow-

er over persons and property which enables the society to prohibit or regulate all things inimical to its comfort, safety, health, and welfare. (U.S. Bur. Outdoor Recreation 1974)

Also see **Eminent domain**, **Just compensation**, and **Taking**.

Policy

1. A definite course or method of action selected by a governmental agency, institution, group or individual from among alternatives and, in the light of given conditions, to guide and usually determine present and future decisions.

A specified decision or set of decisions designed to carry out such a chosen course of action. (Webster 1963)

2. A specific decision or set of decisions together with the related actions designed to implement them. (Webster 1963)

3. The specification in concrete details of ways and means for the attainment of **goals** and **objectives**. (Hill 1968)

Policy plan

This term is sometimes used to describe a formal plan document consisting entirely of a set of **policies** unaccompanied by maps differentiating the **planning area** into districts where some policies apply while others do not.

In contrast, a plan whose formal plan documents consist mainly of a map on which land use regulation districts are indicated is sometimes called a **paper plan** or “map plan”. While “paper plans” are accompanied by such explanatory written information as is necessary to convey their meaning, the basic regulatory document is still the map. (C.F.S.)

Political boundary

A boundary which marks the limits of a political jurisdiction. The bound-

aries of cities, counties, states and nations are political boundaries. Lesser political boundaries limit tax districts, legislative districts, etc. (*Banks 1964*)

Political determinism

A particular point of view in planning which advocates that all resource use and allocation decisions should be made via the political process—i.e., by elected representatives and legislation.

In theory, politics is our society's means for attaining some needed resolution of issues via compromise from the often conflicting demands on a resource by different groups. This point of view believes that elected representatives' decisions are responsive to and representative of the collective judgments of their constituents. Politics thus is viewed as the process by which society makes group choices about resource use allocation, passes final judgment upon interim administrative decisions and conveys the right (via legislation) to regulate resource use—be the resource some **commodity** such as timber or the exercise of private **property rights**. It is believed that because political decisions are societal choices they are the best choices that can be made and thus should be the basis for making planning decisions. (*C.F.S.*)

Political institutions

A society's system of legal rules and principles. (*Webster 1963*)

Pollution

1. Any substance or energy form (heat, light, noise, etc.) which alters the state of the **environment** from what would naturally occur. Especially associated with those altered states which human value judgments have decreed as bad. (*E.C.T.*)

2. Pollution is best considered an activity of man, which directly or indirectly results in the addition to water, air or soil, of matter or energy which has a deleterious effect on living organisms or structures it is desirable to pre-

serve, or which reduces the quality of water, air or soil for any subsequent use. In this context such terms as natural pollution and visual pollution (not referring to decreased visibility due to air pollution) are meaningless and should not be used. (*Russell 1974*)

3. Pollution is the presence of matter or energy in an unusual or unintended place. (*Yapp 1972*)

4. The presence in the environment of one or more contaminants, nuisances, and the like in sufficient quantities and of such characteristics and duration as to be injurious or irritating to human, plant, or animal life, to health, or to property, or to unreasonably interfere with the enjoyment of life or property. (*Sesco, et al. 1973*)

Pollution criteria. See **Criteria**.

Pollution standard. See **Standard**.

Positive feedback. See **Feedback loop**.

Possibly extinct species. See **Species**, recently extinct or possibly extinct.

Potential. See **Biotic potential**.

Poverty, absolute

A standard of living below the minimum needed for maintenance of life and health. (*O'Connell 1974*)

Also see **Poverty, relative**.

Poverty, relative

A condition characterized by a scarcity rather than a lack of economic necessities. A relatively poverty-stricken person is poor in comparison with a majority of others in his society, but his level of living usually does not constitute an immediate threat to life or health. (*O'Connell 1974*)

Power. See **Social power**.

PPBS. See **Planning-Programming-Budgeting System**.

PPM. See **Parts per million**.

Prairie

An extensive tract of level or rolling

land that was originally treeless and grass covered.

*A prairie is usually characterized by a deep fertile soil. (*Amer. Soc. Range Manage. 1964*)

Pre-existing use. See **Use, pre-existing.**

Preferable species

Range management usage. Species that are preferred by animals and are grazed by first choice. (*Amer. Soc. Range Manage. 1964*)

Also see **Ice cream species.**

Preference. For range management usage see **Grazing preference.**

Pre-law strip mining. See **Mining, pre-law strip.**

Premature grazing. See **Grazing, premature.**

Prescribed burn

Intentional application of fire to **wildland** fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc. as allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain planned objectives of silviculture, wildlife management, grazing, fire-hazard reduction, etc. It seeks to employ fire scientifically so as to realize maximum net benefits with minimum damage and at acceptable cost. (*Ford-Robertson 1971*)

Also see **Controlled burn.**

Prescribed cut. See **Allowable cut, definition 2.**

Prescribed yield. See **Allowable cut, definition 2.**

Pressure group (Interest group, Special interest group)

1. Any **special interest group** which actively advocates for special consideration of its resource use goals. (*C.F.S.*)

2. Any politically active group with a common set of values about re-

source use allocation. Pressure groups seek to influence decisions on resource use allocation in excess of their proportional representation in the planned-for populace by seeking preferential consideration for their resource use choices. (*C.F.S.*)

3. Any group having a distinct ideology or set of goals and attempting to achieve those goals through the use of organized means of interaction, such as **lobbying.**

Pressure groups may be distinguished from the broader category of special interest groups by their somewhat more formal organization and their more noticeable activity over time. (*O'Connell 1974*)

4. A voluntary association of citizens who attempt to influence public policy. An interest group may be formed solely to influence policy or political activity may be only one of its many activities.

Interest groups affect policy through lobbying, raising money for political campaigns, promising to "deliver" votes on election day or workers in political campaigns, developing some special expertise, or having some special relationship with an agency in the government bureaucracy.

Interest groups are the most important unit of analysis in pluralist theory, for they mediate between an individual citizen's desires and the political parties.

Two major differences between American parties and interest groups are that parties compete for office, whereas interest groups do not, and that interest groups present a homogeneous interest, whereas parties have a heterogeneous clientele. (*O'Connell 1974*)

5. Also see **Special interest group,** and **Pluralism.**

Prestige. See **Social prestige.**

Primary conversion

The initial steps in the process of

converting a felled or fallen tree to lumber—e.g., topping, trimming limbs, removal of bark, sawing into logs, etc. (*Ford-Robertson 1971*)

Primary effect. See **Direct effect.**

Primary facility

Transportation planning usage. Primary facilities provide access and service to large land areas encompassed and served by the public transportation system. They include public transportation facilities and form the basic framework around which the **transportation network** is designed. A substantial percentage of the traffic served by these facilities is public service traffic, and emphasis is given to travel speed and efficiency. (*After U.S. Forest Serv., FSM 7705.41, Aug., 1975*)

Also see **Secondary facility** and **Tertiary facility.**

Primary output. See **Output, primary.**

Primary range. See **Range, primary.**

Primary sewage treatment. See **Primary wastewater treatment.**

Primary succession. See **Succession, primary.**

Primary treatment. See **Primary wastewater treatment.**

Primary wastewater treatment (Primary treatment, Primary sewage treatment)

The first treatment given to raw sewage collected from household and commercial sources. Typically the process first separates floating solids by screening. The undigested material is then piped into settling tanks where, depending on the temperature and length of stay, varying amounts of suspended solids are removed by gravity precipitation. Primary treatment removes most of the floating solids, 50 percent of the **suspended solids** and at best only about 35 percent of the organic waste and **biochemical oxygen demand** from wastewater. (*After SESCO et al. 1973, Wash. State Univ., Coop.*

Ext. Serv. 1972 and Mc Gauhey 1968,

Prime agricultural land

1. All land which qualifies for rating as Class I or as Class II in the U.S. Soil Conservation Service land use capability classifications. (*Eisner 1969*)

Also see **Land capability class.**

2. Land which has returned from the production of unprocessed agricultural plant products an annual gross value of not less than two hundred dollars (\$200) per acre for three of the previous five years. (*Eisner 1969*)

3. Land identified (after considering the long term productive potential and topographic position of the soil(s), climatic factors, and availability and quality of water) as being required for the economic production of specific agricultural commodities that are designated by local units (of government). (*J.H.H.*)

4. Land meeting any of the following four criteria: (1) Class I or II of the U.S. Soil Conservation Service land capability classification scheme, (2) a **Storie index** rating of 80 to 100, (3) a carrying capacity (see **Carrying capacity, range**) of one animal unit per acre (4) a gross annual revenue of \$200 per acre in unprocessed, plant production or (5) land in fruit or nut-bearing trees, vines or bushes that have less than a 5-year nonbearing period and return not less than \$200 per acre (*Anderson, Gustafson and Boxley 1975*)

Primitive Area

1. A large tract within a U.S. National Forest set aside for preservation in natural condition with no alteration or development beyond measures for fire protection being permitted. (*Webster 1963*)

According to the **Wilderness Act** of 1964 the administrative classification "Primitive Area" will cease to exist as of September 1974. By that date those Primitive Areas considered to be of

wilderness quality as defined by the Wilderness Act will be reclassified as **Wilderness Areas**. (*After Wilderness Act 1964*)

2. As defined in the 1929 U.S. Forest Service regulation creating the "Primitive Area" classification. Areas within which, to the extent of the Department of Agriculture's authority, there "will be maintained primitive conditions of environment, transportation, habitation, and subsistence, with a view to conserving the value of such areas for purposes of public education, inspiration, and recreation. Within any area so designated no occupancy under the special-use permit shall be allowed, or the construction of permanent improvements by any public agency be permitted, except as authorized by the Chief of the Forest Service or the Secretary of Agriculture."

Supplemental instructions sent to Forest Service Regions indicated that "the establishment of a Primitive Area ordinarily will not operate to withdraw timber, forage or water resources from industrial use, since the utilization of such resources, if properly regulated, will not be incompatible with the purposes for which the area is designated." (*Calif., Univ., Wildland Res. Cent. 1962*)

3. These areas are extensive natural, wild and undeveloped areas, usually in a setting far removed from the sights, sounds, and smells of civilization. Essential characteristics are that the natural environment has not been disturbed by commercial utilization and that the areas are without mechanized transportation. The area must be large enough and so located as to give the user the feeling that he is enjoying a wilderness experience. Activities in Primitive Areas involve camping out on one's own without mechanized transportation, permanent shelter or other conveniences. There is no development of public roads, permanent

habitations or recreation facilities except trails. No mechanized equipment is allowed except that needed for management and protection purposes. Administration is usually by the Federal Government, some state agencies, or private landowners such as large timber and mining companies. (*Eisner 1969*)

4. In common usage, Primitive Areas are those **backcountry** types of **wildlands** which show no obvious evidence of permanent human uses and in which people are only transitory visitors. Some use the terms "primitive" and "wilderness" interchangeably to refer to all areas displaying no obvious evidence of present or previous human uses—other than foot or pack animal trails. Others make a distinction between the two, using "primitive" to refer to all areas possessing wilderness qualities and restricting the use of "wilderness" to only those portions of the larger primitive area which have been designated as "Wilderness Areas" according to the Wilderness Act of 1964. (*After A.W.M.*)

Primitive recreation. See **Recreation, primitive.**

Principles and Standards

Guidelines for water and related land resources planning established by the U.S. Water Resources Council for Federal agencies whose activities involve planning and development of water resources. (Published in Federal Register; 38(174): 24777-24869, "Water and Related Land Resources, Establishment of Principles and Standards for Planning.") The "Principles" provide the broad framework for planning activities and include the conceptual basis for planning. The "Standards" provide for uniformity and consistency in comparing, measuring, and judging beneficial and adverse effects of alternative plans. (*U.S. Dep. Agric. 1974*)

The "Principles and Standards" specify two main objectives to be reflected in the planning: national economic development and enhancement of environmental quality.

Also specified is the accounting system which gives four required accounts in which all effects of programs are to be discussed; **national economic development, regional economic development, environmental quality, and social well being.** (*After U.S. Dep. Agric. 1974*)

Private property

The exclusive right to the possession, use or disposal of property or goods. Private property can be real property, land and the buildings fixed on it, or personal property—that is movable property.

The concept of "private property" is the creation of man in society and thus subject to such intrusions upon it as society requires for the general welfare. (*Abrams 1971*)

Probabilistic Model. See **Model, probabilistic.**

Process

The action of moving forward progressively from one point to another on the way to completion.

The action of passing through continuous development from a beginning to a contemplated end.

The action of continuously going along through each of a succession of developmental stages. (*Webster 1963*)

Land use planning is often described as being a "process" rather than a single, finite, irreversible event in time or space. (*C.F.S.*)

For geologic usage see **geomorphic process.**

Producer organism (Producer, Autotrophic organism)

1. An organism that can utilize radiant energy (i.e., sunlight) to synthesize organic substances from inorganic materials. (*Hanson 1962*)

2. Organisms, largely green plants, which are able to manufacture food from simple inorganic substances by fixation of light energy. (*Odum 1971*)

For the other two divisions in this particular classification of **biotic community organisms** also see **Consumer organism** and **Decomposer organism.**

Producer surplus

In economics, the difference between the price that a producer sells a good or service at and the amount that he would be willing to accept in exchange for the good or service. (*E.C.T.*)

Also see **Consumer surplus.**

Production function

A mathematical relationship (frequently presented as a graph) which shows how inputs of various physical factors are related to changes of output—e.g., the effect of different amounts of fertilizer or thinning on the rate of timber production. (*After H.J. V.*)

Productivity, abiotic

The amount of material yielded by an inorganic, renewable resource process (e.g., abiotic products include water, sand, gravel). (*C.F.S.*)

Productivity, biotic

1. The amount of living matter actually produced by the unit being discussed. (*E.C.T.*)

2. The growth products and by-products of living organisms (e.g., wood, meat, other plant fibers) (*C.F.S.*)

Also see **Productivity, primary, Productivity, secondary and Productivity, tertiary.**

Productivity, primary (Basic productivity)

1. The rate at which energy is stored by the photosynthetic and chemosynthetic activity of **producer organisms** (chiefly green plants) in the form of organic substances that can be used as food materials. (*Odum 1953*)

2. The rate of new **biomass** addition (weight growth) on photosynthetic (i.e., plant) organisms. (*After Parsons and Takahashi 1973*)

Also see **Productivity, secondary** and **Productivity, tertiary**.

Productivity, secondary

1. The rate of new **biomass** addition (weight growth) on plant eating (herbivorous) animals. (*After Parson and Takahashi 1973*)

2. The rate of energy storage by **consumer organisms**. (*Odum 1971*)

Also see **Productivity, primary** and **Productivity, tertiary**.

Productivity, tertiary

The rate of new **biomass** addition (weight growth) on meat eating (i.e., carnivorous) animals. (*After Parsons and Takahashi 1973*)

Also see **Productivity, primary** and **Productivity, secondary**.

Profile. For graphic representation methods usage see **Profile view** and for soil terminology usage see **Soil profile**.

Profile view

An illustration in which the features coinciding in space with the plane of sectioning are strongly emphasized (usually by thick linework). Features in the background are usually shown with much thinner linework and without any reduction in size in proportion to their increasing distance from the plane of sectioning (as would occur if they were drawn according to the rules of **linear perspective**). Underground features are seldom shown in "profile" type drawings nor is there ever any exaggeration of the scale of vertical or horizontal features. (*C.F.S.*)

Also see **Cross section**.

Program

1. An activity or combination of activities carried out to meet an objective. (*U.S. Forest Serv. 1972B*)

2. A coordinated organizational endeavor which is defined in terms of the

various activities required to produce specified final outputs and end results. (*U.S. Forest Serv. 1972B*)

A major agency endeavor, mission oriented, which fulfills statutory or executive requirements, and which is defined in terms of the principal actions required to achieve a significant end objective. (*U.S. Gen. Account. Off. 1969*)

Program element

A subdivision of a **program** category which comprises the specific products that contribute to an agency's objective. If an agency's operating program is distributed over several program categories each part of the operating program identified by a discrete program category is a program element. (*U.S. Gen. Account Off. 1969*)

Program evaluation and review technique. See **Critical path method**.

Programming

The process of deciding on specific courses of action to be followed in carrying out planning decisions and objectives. It also involves decisions in terms of total inputs required or total costs to be incurred over a period of years as to personnel, material, and financial resources to be applied in carrying out **programs**. (*After U.S. Forest Serv. 1972B and U.S. Gen. Account. Off. 1969*)

Prohibition zoning. See **Zoning, prohibition**.

Project (Land sales or development project)

Usage in the defeated 1973 bill for a **National Land Use Policy and Planning Assistance Act**. Any of the activities set forth below which occur ten miles or more beyond the boundaries of any **Standard Metropolitan Statistical Area** or of any other **general purpose local government** certified by a governor as possessing the capability and authority to regulate such activi-

ties: (1) the partitioning or dividing into fifty or more lots for sale or resale primarily for housing purposes within a period of ten years of any tract of land, or tracts of land in the same vicinity, owned or controlled by any developer; (2) the construction or improvement primarily for housing purposes of fifty or more units within a period of ten years on any tract of land, or tracts of land in the same vicinity, owned or controlled by any developer, including the construction of detached dwellings, town houses, apartments, and trailer parks, and adjacent uses and facilities, whatever their form or ownership or occupancy; (3) such other projects as may be designated by a State. (*U.S. Congr., Senate. Com. Inter. Insular Aff. 1973*)

Projection

1. An extrapolation of a series of past data to predict future conditions and occurrences. The accuracy of a projection is very dependent on past trends continuing, or else changing in some known manner.

A "projection" differs in a strict sense from a forecast, which is also a prediction of future conditions and occurrences, but is based on an understanding of the system being discussed from current and past data rather than merely continuing and adjusting past trends. Although the distinction may exist, the dividing line between the two terms is imprecise. (*E.C.T.*)

2. Projections are conditional forecasts of the future. They are based upon stated assumptions about factors that are expected to impact on future conditions. Projections reflect historical development and economic activity as modified by discernible trends determined by analysis of present and past relationships. If there are no changes in the objectives of the people, if limits of resource availability are not reached, if anticipated technology

is attained, and if the influence of external forces remains constant, projections could reasonably be expected to chart the future. (*U.S. Dep. Agric. 1974*)

Also see **Forecast**.

Project planning (Operational planning)

Types of planning concerned with physical undertakings (such as a dam). Project planning incorporates a greater range of specific elements than **functional planning** and, thus, deals with more numerous and diverse parts. (*Branch 1967*)

See **site planning** for the distinctions between project planning and site planning.

Proper grazing. For range management usage see **Use, proper**.

Proper stocking. See **Stocking, proper**.

Property

1. The dominion or indefinite right of use or disposition which one may lawfully exercise over particular things or subjects, land, improvements or objects of value to which rights of **ownership** and control may be acquired. (*U.S. Bur. Outdoor Recreation 1974*)

2. The social, and sometimes legal, set of relationships of rights and obligations between people concerning the use of an object. An object in these relationships may be material or non-material, such as a trademark. (*O'Connell 1974*)

Property rights

The sum total of the rights pertaining to property **ownership**. In the case of real property it embraces the right to quiet enjoyment, the right to sell, to mortgage, to lease, to bequeath, to regain possession at the end of a lease, to build and remove improvements, and to control the property's use within the law. In short, it describes the scope of legal protections granted to property ownership. (*Abrams 1971*)

Proper use. For range management usage see **Use, proper**.

Proper utilization. For range management usage see **Use, proper**.

Prospecting

The removal of **overburden**, core drilling to obtain subsurface samples, construction of roads or any other disturbance of the surface for the purpose of determining the location, quantity or quality of a mineral deposit. (*Grim and Hill 1974*)

Proxemics

The study of man's use of social and **personal space**. (*Worthington 1974, citing Hall 1966*)

Proxy value

A value assigned to a good or service for evaluation purposes when the good or service is not bought nor sold and an established monetary price does not exist. (*E.C.T.*)

Also see **Market value**.

Psychological carrying capacity. See **Carrying capacity, psychological**.

Public domain

The territory ceded to the Federal government by the original thirteen states, together with certain subsequent additions by cession, treaty, and purchase. (*U.S. Forest Serv., FSM 7140.5, July 1967*)

Public involvement

1. The opportunity for maximum feasible participation by citizens in rulemaking, decision making and land use planning, including public hearings, advisory mechanisms and such other procedures as may be necessary to provide public input in a particular instance. (*After U.S. Congr., House Represent., Com. Inter. Insular Aff. 1975*)

2. The use of appropriate procedures for informing the public, obtaining early and continuing public partici-

pation and considering the views of interested parties in planning and decision-making processes.

The "public" referred to includes individuals, local, state, regional and national public service organizations and interest groups. It also includes state, local and other Federal agencies which have jurisdiction, special expertise or information to offer relevant to the total planning and implementation picture. (*U.S. Forest Serv., FSM 8212, Oct. 1973*)

Public land

Land for which the title and control rests with a government—Federal, state, regional, county, or municipal. (*E.C.T.*)

Public participation. See **Public involvement**.

PUD. See **Cluster development**.

Pyramid of biomass

When the total weight of individuals at successive **trophic levels** in a **food chain** is plotted, a gradually sloping pyramid usually results—regardless of the individual size of the **producer organisms** or **consumer organisms**, and regardless of whether predators or parasites are considered. This "pyramid of biomass", in effect, gives a picture of the over-all effect of food chain relations for the ecological group as a whole.

The number of organisms that can be supported at higher trophic levels actually depends not on the amount of food organisms present at any one time, but on the number being replaced as fast as some are eaten. (*Odum 1953*)

In such pyramids if the **biomass** of the various trophic levels is taken at one instant in time, a lowest trophic level consisting of organisms with short life times commonly has a smaller **standing crop** biomass than the next higher level. However if the total

productivity of biomass at different levels in such pyramids is summed on an annual basis, the expected pyramidal biomass relationships will be observed, because of the larger total weight of biomass produced over such periods of time by the commonly small and short-lived but much more numerous and rapidly reproducing organisms in the lowest trophic level. (C.F.S.)

Pyramid of energy

A graphical representation of the rate of energy flow and/or energy productivity at successive trophic levels in a food chain or for a complete biotic community.

Of the three types of ecological pyramids, the energy pyramid gives by far the best overall picture of the functional nature of biotic communities since the number and weight of organisms that can be supported at any level in any situation depends not on the amount of fixed energy present at any one time in the level just below, but rather on the rate at which food is being produced. In contrast the pyramid of numbers and pyramid of bio-

mass, are pictures of the standing states, i.e., organisms present at any one moment, while the energy pyramid is a picture of the rates of passage of food mass through the food chain. Its shape is not affected by variations in the size and metabolic rate of individuals, and, if all sources of energy are considered, it must always be right side up (i.e., with the largest numbers at the base) because of the second law of thermodynamics. (Odum 1971)

Pyramid of food production rates. See Pyramid of energy.

Pyramid of numbers (Eltonian pyramid, Food pyramid)

1. A graphic representation of the food chain which indicates the large numbers of producer organisms (i.e., plants) at the base of the food chain, and the progressively decreasing numbers of herbivores (plant eaters) and carnivores (meat eaters) higher up in the food chain. (After Odum 1971)

2. Elton's concept that in most food chains the number of individuals decreases in each succeeding stage, with large numbers of animals occurring at the base and a few large ones at the top. (Hanson 1962)

Q

Quality of life

1. This quality is seen as a measure of the degree to which a society offers effective opportunity to enjoy the "good life". The components of the "good life" are a combination of goods and services available in a total environment; physical, social, and cultural. Their precise composition would be a matter of personal judgement about which widely differing opinions would be held. The "quality of life", therefore, is an essentially subjective concept. It may, however, be that for a particular community a reasonable

consensus could be found about a range of choice of goods and services and about the qualities of the environment which should be offered. (Coombs 1972)

2. The measure of harmony between individual and cultural value systems and the capacity and opportunity for their realization. (L.W.)

3. A broad, all-encompassing term used to refer to the quality characteristics of all the aspects of one's environment. (Sesco, et al. 1973)

Questionnaire

1. A set of questions for obtaining

statistically useful or personal information from an individual. (*Webster 1963*)

2. U.S. Office of Management and Budget usage. A form provided by a government agency to solicit information and comments from the public which requires prior approval by the Office of Management and Budget (OMB) if submitted to ten or more people, in contrast to a **response form** which does not require OMB approval. A form becomes a questionnaire if (a) it is distributed to members of the public who have not requested information material or are not directly affected by possible management actions, or (b) it asks any questions relative to the nature or attitudes of the respondent beyond name, address, and organizational affiliation, or (c) it con-

tains more than brief descriptions distinguishing alternative actions, chapter headings to aid in review, and space for whatever comments the respondent may wish to make. (*After U.S. Forest Serv. Wash. Off. 1974*)

3. A printed research form presented to the person from whom data are sought. Ordinarily, it is fixed with respect to the wording and order of the questions. These may include agreement/disagreement items, items which are to be ordered by rank, items in which the respondent is asked to choose one of two or three different statements as coming closest to his or her **opinion** or **beliefs**, and open-ended questions in which he or she provides one-word or short-answer responses. (*O'Connell 1974*)

Also see **Response form**.

R

Raindrop erosion. See **Erosion, splash**.

Rainfall intensity

The rate at which rain is falling at any given instant, usually expressed in inches per hour. (*Soil Conserv. Soc. Amer. 1970*)

Range

1. All land producing naturalized or native **forage** for animal consumption, and lands that are revegetated naturally or artificially to provide a forage cover that is managed like naturalized or native vegetation. Generally considered as land that is not cultivated. (*After Amer. Soc. Range Manage. 1964*)

2. Embraces **rangelands** as well as many forestlands which support an understory or periodic cover of herbaceous or shrubby plants suitable for grazing without impairing other forest values. (*D.E.H. and B.W.*)

Range allotment (Allotment)

An area designated for the use of a

prescribed number of cattle or sheep, or by common use of both under one plan of management. (*Amer. Soc. Range Manage. 1964*)

Range, annual

Range on which the principal forage plants are herbaceous species which only live for one year. (*After Amer. Soc. Range Manage. 1964*)

Range, closed

A **suitable range** that is closed to grazing by domestic livestock. (*Amer. Soc. Range Manage. 1964*)

Range condition

The state and health of the **range** based on what it is naturally capable of producing. (*Soil Conserv. Soc. Amer. 1970*)

Range condition class

One of a series of arbitrary categories used to classify **range condition**, usually expressed as either excellent, good, fair, or poor. (*Soil Conserv. Soc. Amer. 1970*)

Range improvement

"Physical improvement." Any structure or excavation to facilitate management of range or livestock.

"Biological improvement". An increase in the grazing capacity of range. Improvement in range condition. (*Amer. Soc. Range Manage. 1964*)

Range, key winter

The smaller portion of the total year's range where big game animals find food and/or cover during severe winter weather.

"Key winter" areas limit the number of animals the range can support. (*U.S. Forest Serv. Lolo Natl. Forest 1974B*)

Rangeland

1. Land on which the natural plant cover is composed principally of native grasses, **forbs** or shrubs valuable for forage. (*U.S. Forest Serv. 1972A*)

2. Land used for grazing by livestock and big game animals on which the natural potential **climax community** of plants is dominated by grasses, grass-like plants, forbs, and shrubs. (*U.S. Soil Conserv. Serv. 1970*)

3. Land where the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs, where natural grazing and browsing was an important influence in its precivilization state, and that is more suitable for management by ecological rather than agronomic principles.

Some "rangelands" have been or may be seeded to introduced or domesticated plant species. (*Anderson, et al. 1962*)

4. Land on which the (climax or natural potential) plant community is dominated by grasses, grass-like plants, forbs, or shrubs suitable for grazing or browsing and present in sufficient quantity to justify grazing or browsing use. Includes rangelands revegetated naturally or artificially to provide cover

that is managed like native vegetation. Rangelands include natural grasslands, savannas, shrublands, many deserts, tundra, alpine communities, coastal marshes, and wet meadows.

Rangeland Grazing System

U.S. Forest Service usage. This system includes all those activities that bear directly upon management, protection, and development of the National Forests and Grasslands for livestock grazing. It also includes the cooperative aspects of state and private forestry associated with producing livestock on non-Federal forest range. Research provides the system with management alternatives that relate range productivity with other forest and range land resources.

One of the six "systems" established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act of 1974**. It has grouped its various programs into these six "systems", each of which incorporates all the activities concerned with developing and managing a specific resource. (*After U.S. Forest Serv. 1974A*)

The six "systems" are: **Land and Water, Timber Resource, Outdoor Recreation and Wilderness, Rangeland Grazing, Wildlife and Fish Habitat, and Human and Community Development.**

Range management (Range planning)

The art and science of planning and directing range use to obtain sustained maximum animal production, consistent with perpetuation of the natural resources. (*Amer. Soc. Range Manage. 1964*)

Range, open

1. All suitable range of an area upon which grazing is permitted. (*Amer. Soc. Range Manage. 1964*)

2. Ranges which have not been fenced into management units. (*Amer. Soc. Range Manage.* 1964)

Range planning. See **Range management.**

Range, primary

Areas which animals prefer to use and over which they will graze when management is limited.

The areas on which overuse will occur before **secondary range** is used when animals are allowed to shift for themselves. (*Amer. Soc. Range Manage.* 1964)

Ranger District multiple use plan

U.S. Forest Service usage. A document, prepared for each Ranger District and consisting of sub-(administrative) Region multiple use guides supplemented at the Ranger District level, that serves to direct and coordinate National Forest land management, development, protection, and use until this role is assumed by part I of the **National Forest land use plan**. (*W.W.*)

Range readiness

The stage of growth of the important **palatable** plants on the **range** and the condition of soil which permit grazing without undue compacting of the soil or endangering the ability of the plants to maintain themselves. (*Soil Conserv. Soc. Amer.* 1970)

Range, secondary

Range which is lightly used or unused by livestock under minimal management and will ordinarily not be fully used until the **primary range** has been overused. (*Amer. Soc. Range Manage.* 1964)

Range site

1. A distinctive kind of **rangeland** that differs from other kinds of rangeland in its potential to produce native plants. (*Soil Conserv. Soc. Amer.* 1970)

2. An area of land having a combination of soil, climatic, **topographic**

and natural biotic factors that is significantly different from adjacent areas.

These environmental areas are considered as units for purposes of discussion, investigation and management. Changes from one site to another represent significant differences in potential forage production and/or differences in management requirements for proper land use. (*Amer. Soc. Range Manage.* 1964)

Range suitability

The adaptability of a range to grazing by livestock and/or game. (*Amer. Soc. Range Manage.* 1964)

Range, suitable

Range which is accessible to livestock or game and which can be grazed on a **sustained yield** basis without damage to other resources. (*Amer. Soc. Range Manage.* 1964)

Range, transitory

Land that is suitable for grazing use of a nonenduring or temporary nature over a period of time. For example, on particular disturbed lands, grass may cover the area for a period of time before being replaced by trees or shrubs not suitable for forage. (*U.S. Forest Serv., Lolo Natl. Forest* 1974A)

Range, unsuitable

An area which has no value for, or which should not be used by livestock because of steep topography, barrenness, dense timber, lack of forage, or unstable soils. (*Amer. Soc. Range Manage.* 1964)

Range use. See **Use**, degree of.

Rare and Endangered Species Act

A misnomer for the Endangered Species Conservation Act of 1969. This act has now been repealed and replaced by the **Endangered Species Act of 1973**.

See **Endangered Species Act of 1973**.

Rare species. See **Species**, rare.

RAU. See **Resource analysis unit.**

Raw land (Undeveloped land)

A term of comparison sometimes used to contrast land which has been built upon (i.e., "developed") or subdivided in preparation for development with undeveloped and unsubdivided (i.e., "raw") land. (*C.F.S.*)

RCD. Resource conservation district. See **Soil Conservation District.**

RCU. See **Resource capability unit.**

Recently extinct species. See **Species, recently extinct or possibly extinct.**

Recharge

The addition of water to an aquifer that occurs naturally from infiltration of rainfall and from water flowing over earth materials that allow water to infiltrate below the land surface. (*Feth 1973*)

Reclamation

Mining usage. The filling in of open pits, grading of the mined area, reduction of high walls, replacement of top soil, planting, revegetation and such other work as is necessary to restore an area of land affected by surface mining operations.

The process of reconvertng mined land to other forms of productive uses. (*After Grim and Hill 1974*)

Reclamation, effective

Mining usage. Rehabilitation of mining-affected land to make it acceptable for designated purposes, with protection of the natural resources and aesthetic value of adjoining areas. (*Counc. Agric. Sci. Technol. 1973*)

Reconnaissance soil map. See **Soil map, reconnaissance.**

Reconnaissance soil survey. See **Soil map, reconnaissance and Soil survey.**

Reconnaissance survey

U.S. Forest Service usage. A preliminary survey usually executed rapidly

and at a relatively low cost. (*U.S. Forest Serv., FSM 7140.5, July, 1967*)

Recreation

1. Leisure time activity such as swimming, picnicking, boating, hunting and fishing. (*Federal Register 38(174:24803)*)

2. Use of leisure time for personal satisfaction and enjoyment. Recreation is a basic human need. It may be undertaken individually or with others. It may be planned or spontaneous. It may be passive or active, may or may not require skills and training, and may or may not require a designated area. (*U.S. Bur. Outdoor Recreation 1974*)

3. Recreation is an exceedingly variable term meaning almost anything people do with their leisure. It is not a resource but an activity compounded of two parts, recreationists and recreation environments. Resources such as timber, forage, water, or minerals exist in land. Recreation exists in the mind and takes place in an environment based on the land.

Outdoor recreation involves the protection, preservation, development, public use, and enjoyment of scenery, water, primitive or natural landscape (including roadless areas), wildlife, natural phenomena (e.g., petrified wood), and archeological and historical sites. (*Eisner 1969*)

Recreation easement. See **Easement, recreational.**

Recreational experience levels

U.S. Forest Service usage. The extent to which various classes of outdoor recreation experiences provide opportunities for satisfying some of the basic needs of individuals—such as to find isolation and solitude, to socialize, to achieve self-fulfillment, for aggression outlets, etc.

The levels in the Forest Service system are qualitatively broken into six classes based upon the extent to

which; (1) outdoor skills are required, (2) the natural environment has been modified to facilitate use and, (3) comfort and/or convenience facilities are provided. (*After U.S. Forest Serv., FSM 2330.5-3, Jan., 1969*)

Recreational experience quality

The quality of recreational experience is the degree of excellence, value, or worth of any form of recreational experience determined through personal judgments and preferences. Consensus and individual variation form expectations that, depending upon the extent to which they are achieved, specify the degrees of quality judgments. Consensus may provide relative value scales or standards that may offer some universal basis for quality judgments. Individual variation, as shown through personal judgments and preferences, is the deviation from consensus as a consequence of individual intelligence and qualities of personality as influenced by education, experience, perception, and socialization and modified by external influences such as area, design facilities, activities, human relations, impacts, finances, health and safety, weather, travel, and time. (*A.W.M.*)

Also see **Recreational quality**.

Recreational quality

The degree to which a recreational experience or area normally contributes to the physical and psychic well-being of recreationists. Thus a thoroughly worn area usually offers lower recreational quality than areas presenting a fresh and natural scene. Individual tastes differ, and an experience is of high quality only to people for whom it provides a large measure of enjoyment or well-being. (*Wagar 1964*)

Also see **Recreational experience quality**.

Recreational river area

Wild and Scenic Rivers Act usage. Those rivers or sections of rivers that

are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past. (*After U.S. Forest Serv. 1974*)

Recreation and park planning

An organized procedure to determine **goals, objectives**, and actions in recreation and park functions. Such planning is one unit of **comprehensive planning**. It involves the consideration of the total environment, physical and social, and the role that recreation plays in the **master plan** for a given area. (*U.S. Bur. Outdoor Recreation 1974*)

Recreation area, developed

A relatively small, distinctly defined area where concentrated public use for the more traditional recreation purposes predominates—e.g., campgrounds, picnic areas, swimming areas. (*U.S. Forest Serv. Region 9 1975*)

Recreation, concentrated

Those types of activities associated with **developed recreation sites**—such as campgrounds, picnic grounds, ski areas, fishing ramps, scenic overlooks, interpretive sites, etc. (*U.S. Forest Serv., Lolo Natl. Forest 1974B*)

Recreation day

A standard unit of use for an area or activity consisting of a visit by one individual to a recreation development or area for recreation purposes during any reasonable portion or all of a 24 hour period. This corresponds roughly with what is termed a “recreation visit”.

For example, if the average stay at a picnic site were four hours then a four-hour visit to the picnic site by one person would be a recreation day. (*Dyrland 1973*)

Recreation, dispersed

1. Recreation of various kinds that occurs generally throughout a large

area, and is not confined to a specific place. (*U.S. Forest Serv., FSM 2300 R-8*)

2. Scattered, individual outdoor recreation activities normally not identified with developed facilities or areas of group concentration. (*U.S. Forest Serv., FSM 2300 R-8*)

3. Recreational use of trails, natural lakes, ponds, rivers, streams and generally undeveloped areas. Includes such activities as hiking, back packing, hunting, fishing, snowmobiling, horse back riding and cross-country skiing. (*U.S. Forest Serv. Region 9 1975*)

Recreation, extensive

Low-density, dispersed recreation types—e.g., general hiking and riding, snowmobile use, dispersed camping, hunting, etc. (*Sandpoint Zone Plann. Team 1974*)

Recreation, intensive

High-density recreational activities—e.g., developed camp and picnic grounds, swimming beaches, hiking trails that are major access routes into wilderness areas, all-terrain vehicle areas (except snowmobile courses), etc. (*Sandpoint Zone Plann. Team 1974*)

Recreation land

Land and water used primarily for recreation. (Recreation may be a **secondary** use of land where woodland, cropland, rangeland, etc., is the primary use.) (*U.S. Soil Conserv. Serv. 1970*)

Recreation, primitive

Those types of recreational activities associated with unroaded land—e.g., hiking, backpacking, cross country travel. (*U.S. Forest Serv., Lolo Natl. Forest 1974B*)

Recreation resource

The combination of the natural qualities of land and water areas and the ability and desire of man to use this combination for recreation. (*U.S.*

Forest Serv. 1971)

Also see **Recreation**, definition 3.

Recursive

The process of repeating an operation or group of operations, usually with the result of each repetition being in some way dependent upon the result of the preceding repetition. (*U.S. Gen. Account. Off. 1969*)

Reducer organism. See **Decomposer organism**.

Reforestation

1. The natural or artificial restocking of an area with forest trees; most commonly used in reference to the latter. (*U.S. Forest Serv. 1972B*)

2. Re-establishment of a crop on forest land. (*Ford-Robertson 1971*)

3. "Reforestation" includes measures to obtain natural regeneration as well as tree planting and seeding.

Reforestation is done to produce timber and other forest products, protect watersheds, prevent erosion and improve other social and economic values of the forests, such as wildlife, recreation and natural benefits. (*U.S. Forest Serv., FSM 2472, June, 1973*)

Refuse. See **Mining refuse**.

Regeneration

1. The renewal of a tree crop, whether by natural or artificial means. (*Ford-Robertson 1971*)

2. Regeneration is also used when referring to the young crop itself. (*Ford-Robertson 1971*)

Regeneration cutting

1. Any removal of trees intended to assist **regeneration** already present or to make regeneration possible. (*Ford-Robertson 1971*)

2. "Regeneration cutting" applies generally to the logging stands of **rotation** age or greater, and stands below rotation age which cannot economically be held any longer because of poor stocking, health, thrift, quality, or

composition. (*U.S. Forest Serv., FSM 2471.2*)

3. "Regeneration cutting" applies to all cutting in virgin stands and to all cutting in cutover stands where the overwood components of the stand are over rotation age. (*U.S. Forest Serv., FSM 2471R-3*)

Region

1. A large tract of land; a country. (*Stamp 1961*)

2. A more or less defined portion of the earth's surface, now especially as distinguished by certain natural features, climatic conditions, a special fauna or flora, or the like.

An area space, or place, of more or less definite extent or character.

An area of the earth's surface differentiated (from adjoining areas) by one or more features or characteristics which give it a measure of unity. According to the criteria employed in differentiation, "regions" are termed **physiographic**, political, economic, etc. (*Stamp 1961*)

3. A U.S. Forest Service Administrative unit consisting of several National Forests in one or more states. Within the Forest Service, Regions of this type are known by their number (e.g., Region 5), and the adjective "Regional" often refers specifically to these administrative units. In planning, the Forest Service equivalent of a region as defined in 2, above, is a **planning area**. (*E.C.T.*)

Also see **Region, natural**.

Regional climate (Macroclimate)

The general large-scale climate of a large area or country, as distinguished from the **mesoclimate** and **microclimate**. (*Huschle 1959*)

Regional economic development

One of the four "required accounts" for categorizing, displaying, or "accounting" the beneficial and adverse effects of each alternative plan

formulation for water and related land resources planning specified in the U.S. Water Resources Council's **Principles and Standards** and the U.S. Department of Agriculture's "Procedures" for adhering to them.

Also see **Principles and Standards**. (*After U.S. Dep. Agric. 1974*)

Regional plan

The plan for a **region** (i.e., an area larger than a single city and whose boundaries have typically been designated according to some **physiographic**, biological, political, administrative, economic, demographic or other criteria). (*C.F.S.*)

Also see **River basin plan**.

Regional planning

1. The planning discipline concerned with the clarification of social objectives in the ordering of activities in supra-urban space—that is in any area which is larger than a single city.

"Regional planning" is a discipline, primarily oriented to the future, that looks to the relation between social purposes and spatial arrangements in any area which is larger than a single city. (*After Friedman 1963*)

In the U.S. Forest Service land use planning this is approximately equivalent to its largest land use planning subdivision (i.e., the geographic area to which a **planning area guide** applies) and should not be confused with Forest Service administrative Regions (i.e., administrative units consisting of several National Forests in one or more states). (*E.C.T.*)

Also see **Planning area**.

Region, morphogenetic (Formkreis)

1. A region whose distinguishing landscape characteristics are the result of the operation of particular dominant **geomorphic processes** which have been caused by the occurrence of a certain set of climatic conditions. (*Thornbury 1969*)

2. A region in which, under a certain set of climatic conditions, the predominant geomorphic processes will give to the landscape **land form** characteristics that will distinguish it from those of other areas developed under different climatic conditions. (*Amer. Geol. Inst.* 1962)

3. Related land forms which owe their existence to the action of the same geomorphic process—such as running water or ice action. (*Stamp* 1961)

For analogous uniform land form pattern concepts also see **Region, morphological** and **Region, physiographic**.

Region, morphological

Land units with a high degree of homogeneity in all their morphological (i.e., land surface form) features. (*After Stamp* 1961, citing *Linton* 1951)

“Morphological” regions only refer to areas possessing a uniformity of land surface forms without any implied, underlying speculation as to the processes responsible for those forms.

For analogous uniform land form pattern concepts also see **Region, morphogenetic** and **Region, physiographic**.

Region, natural

1. A part of the earth’s surface characterized by the comparatively high degree of uniformity of structural and climatic features within it. (*Stamp* 1961, citing *Mill* circa. 1910)

“Natural regions” deal not merely with the mutual adjustment of drainage and land forms, but also with the well-marked zones of climate, vegetation, and even human distributions which characterize such forms when situated in similar climatic areas. A natural region should have a certain unity of configuration, climate, and vegetation. The mapping of human conditions has less significance in indicating the major natural geographical regions. Political divisions must be eliminated from any consideration of natural regions. (*Stamp* 1961, citing *Herbertson* 1905)

The basis of the regional division is to be found in nature as a whole, including man, in contrast to a division based on a single element, as in the case of “climatic regions,” “agricultural regions” etc. The basis of the regional division is to be found in regions considered in terms of their, non-human elements. (*Stamp* 1961, citing *Hartshorne* 1951; interpretation of *Herbertson* 1905)

2. The term “natural region” has been used to cover two distinct types of unit-areas of the earth’s surface: (1) those which are marked out as possessing certain common physical characteristics—e.g., a certain kind of structure and surface relief, or a particular kind of climate; and (2) those regions which possess a unity based upon any significant geographical characteristics whether physical, biological or human, or any combination of these, as contrasted with areas marked out by boundaries imposed, frequently for political or administrative purposes, without reference to any geographical unity of the areas. (*Stamp* 1961, citing *Geographical Association* 1937)

3. The concept of the “natural region” is a much debated problem. *Hartshorne* (1951) points out that, while some use the term “natural regions” to indicate something inherent and not arbitrarily imposed, we are fundamentally measuring the different natural criteria in terms of their importance to man. Since the relative importance of the different natural elements to man is certainly not determined by nature as distinct from man, it follows that our systems inevitably have a human basis. In the delimitation of regions, the crux of the matter seems to be “is the region inherent in the landscape or is it the product of criteria applied by the individual geographer?” In other words, is the region an objective or subjective concept? (*Stamp* 1961)

Region, physiographic (Geomorphic province, Geomorphic region, Physiographic province)

1. A region having a particular pattern of relief features or land forms that differs significantly from that of adjacent regions. (*Webster 1963*)

2. A region of similar geologic structure and climate that has had a unified geomorphic history. (*Amer. Geol. Inst. 1962*)

3. An area or division of land in which the pattern of topographic elements (altitude, relief and land forms) are characteristic throughout and as such distinguish it from other areas with different sets of topographic elements. (*Thornbury 1965*)

For analogous uniform land form pattern concepts see **Region, morphogenetic** and **Region, morphological**.

Register of National Natural Landmarks. See **National Registry of Natural Landmarks**.

Regolith

The layer or mantle of loose, non-cohesive or cohesive rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on **bedrock**. It comprises rock waste of all sorts; volcanic ash; glacial drift; **alluvium**; wind-blown deposits; and accumulations of vegetation, such as peat; and soil. (*Soil Conserv. Soc. Amer. 1970*)

Regulatory standard. See **Standard**.

Relative poverty. See **Poverty, relative**.

Release cutting

1. Freeing a tree, or group of trees, from more immediate competition by cutting, or otherwise eliminating, growth that is overtopping or closely surrounding them. (*Ford-Robertson 1971*)

2. Three principal operations come under this classification: (A) Treatments to free desired growing stock trees from over-story vegetation; prin-

cipally, scrub trees, brush, and vines that inhibit their growth or desirable development. (B) Treatments to prevent development of brush and trees that threaten to overtop desired growing stock trees. (C) Removal of grass, weeds, or brush from around individual seedlings or small trees to release them from competition for soil moisture, shade, or smothering as under matted grass or weeds. (*U.S. Forest Serv., FSM 2476.41*)

3. Cutting an immature stand to free the crop trees from excessive competition by removing the excess of an undesired age class (such as a young age class which because of excessive numbers is competing severely with an older but desired regulated age class). (*U.S. Forest Serv., FSM 2471 R-3*)

Relic

Historical or archeological remains usage. Something that is left behind after decay, disintegration or disappearance (as of a structure, a culture, etc.). (*Webster 1963*)

For biologic or ecologic usage, see **Relict**.

Relict (Relic)

1. As related to a **climax community**, fragments of presently existing flora on areas with a historical record of no disturbance and the plant community is assumed to be in near virgin condition. (*Amer. Soc. Range Manage. 1964*)

2. A **biotic community** or species which, through the operation of some compensating or protective environmental features has survived some major change (e.g., climatic, land use) that has altered the general vegetation of the surrounding territory. (*Ford-Robertson 1971*)

3. A remnant of the population of a species that was formerly more widespread. (*Hanson 1962*)

Relief

1. The difference in elevation be-

tween the high and low points of a land surface. (*Amer. Geol. Inst.* 1962)

2. The elevations or the inequalities of a land surface, taken collectively. (*After U.S. Geol. Surv.* 1954)

Remote sensing

Any data or information acquisition technique which utilizes airborne techniques and/or equipment to determine the characteristics of an area.

Aerial photos are the most common form of remote sensing product, but side scanning radar (SLAR) and other pictorial and nonpictorial forms of data collections are also produced by some remote sensing techniques. (*C.F.S.*)

Removal cutting

The removal of the seed source, typically the **seed trees**, after adequate regeneration has taken place. (*U.S. Forest Serv., FSM 2471.22.*)

See **Shelterwood system** for the timing relationships between this cutting type and others in that silvicultural system.

Removal regeneration cutting

Cutting a stand which has an advanced manageable **understory** of 1-20 year old age class **reproduction**. The **seed-tree cutting** is bypassed and all the **overstory** competition is removed in one cutting. The stand is reduced to the single age class for future management. (*U.S. Forest Serv., FSM 2471 R-3*)

Renewable resource (Flow resource, Inexhaustible resource)

1. "Flow resource" and "inexhaustible resource" are grouped here because these categories are conceptually very similar, if not often identical to "renewable resource." (*C.F.S.*)

2. Resource inexhaustibility is only a meaningful concept if employed in the economic sense. "Inexhaustibility" need not imply superabundance compared to demand nor rapid, abundant renewal. A resource may be "inex-

haustible" in the sense that utilization can continue indefinitely because it is only economically feasible to use very small amounts, per unit of time, of resources which are available in only comparatively small physical quantities. (*After Ciriacy-Wantrup* 1968)

3. Resources whose supply becomes available for use at different intervals in time. The use of present supply flows does not diminish future flows and it is possible to maintain use indefinitely provided the use rate does not exceed flow rate.

Many renewable resources can be stored—such as water in a reservoir or mature timber in a stand and such stores can be treated as a stock (i.e., exhaustible) resource. The availability of a flow for replenishing the stock, however, differentiates such stores "flow resources" from truly "nonrenewable resources."

There are two broad classes of "renewable resources" one in which human resource use activities do not significantly alter future flows (ex. wind, tidal and solar energy) and a second class where human activities may increase or decrease future flows (ex. timber growth, soil productivity). (*After Ciriacy-Wantrup* 1968)

4. **Natural resources** are of two types: "renewable" and **non-renewable**. "Renewable resources" are living organisms and others such as soil and water which are closely associated with and affected by living organisms. Non-renewable resources are non-living materials such as minerals and fuels. (*U.S. Bur. Outdoor Recreation* 1974)

Renewable resource assessment. See **Forest and Rangeland Renewable Resources Planning Act of 1974.**

Renewable resource lands

Usage in the defeated 1973 bill for a **National Land Use Policy and Planning Assistance Act.**

Areas where uncontrolled or incom-

patible development which results in the loss or reduction of continued long range productivity could endanger future water, food, and fiber requirements of more than local concern. These lands include watershed lands, aquifers and aquifer recharge areas, significant agricultural and grazing lands, and forest lands.

This is one of the three types of **areas of critical environmental concern** specifically set forth in this bill. The others are **natural hazard lands** and **fragile or historic lands**. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Renewable resource program. See **Forest and Rangeland Renewable Resources Planning Act of 1974**.

Reproductive capacity. See **Biotic potential**.

Reproductive potential. See **Biotic potential**.

Research Natural area. See **Natural Area, Research**.

Reservation and other tribal lands

Usage in the defeated 1973 bill for a national **Land Use Policy and Planning Assistance Act**. "All lands within the exterior boundaries of any Indian reservation, notwithstanding the issuance of any patent, and including rights-of-way, and all lands held in trust for or supervised by any Indian tribe."

The first part of this definition is intended to eliminate pockets of free-patented land inside Indian reservations which might otherwise be subject to laws different from their surroundings. Similarly, the second part of the definition, which includes "all lands held in trust or supervised by any Indian tribe," is intended to cover lands which are Indian country for all practical purposes but which do not enjoy reservation status. The Indian tribal land use planning processes and programs would be largely meaningless if

the tribes could not control key tracts within their reservations which they did not own or lands outside a reservation which they owned or for which they possessed administrative responsibility. (*U.S. Congr., Senate, Com. Inter. Insular Aff. 1973*)

Reservoir Salvage Act (74 Stat. 220)

The Reservoir Salvage Act of 1960 provides for the recovery and preservation of "historical and archeological data (including relics and specimens)" that might be lost or destroyed as a result of the construction of dams, reservoirs, and attendant facilities and activities. (*U.S. Forest Serv., FSM 2361.01, Feb. 1974*)

Residential density

The average number of families living on one acre of land in a given area.

"Gross residential density" is obtained by dividing all land in a defined area used for residences, streets, local schools, local parks and local shopping facilities into the total number of families is said area.

"Net residential density" is determined by dividing the total number of families in a defined area by the total acreage of all parcels of land within the area that is used for residential purposes. (*Eisner 1969*)

Residential land

Land used primarily for permanent dwellings, such as houses, apartments, and housing developments, including adjacent facilities such as underground and surface utilities, access streets and alleys, and other servicing structures, appurtenances, and measures. (*U.S. Soil Conserv. Serv. 1970*)

Resident species. See **Species, resident**.

Resource

1. Anything which is useful for something—be it animal, vegetable, mineral, a location, a labor force, etc. Resources, in the context of land use planning, thus vary from such com-

modities as timber and minerals to such amenities as scenery or scenic viewing points. (C.F.S.)

2. Those aspects of man's environment which render possible or facilitate the satisfaction of human wants and the attainment of social objectives. (Stamp 1961, citing *Encyclopedia of the Social Sciences* 1933)

3. The concept of "resource" presupposes an appraisal of the usefulness of an environment for some purpose. What constitutes a "resource" therefore, is a highly relative concept whose precise definition changes depending upon the planning agent, the planning's purpose, with the state of technological means for using an environment for a purpose, and with the ability to make use within the constraints imposed by existing social institutions (laws, customs, etc.). (After Ciriacy-Wantrup 1968)

Thus, for example, garbage is not a "resource" to those attempting to get rid of their wastes but it is a "resource" to those who are attempting to recover recyclable materials from it—provided existing regulations and separation technology permit them to do this economically. (C.F.S.)

Resource allocation

1. The action of apportioning the supply of a resource to specific uses or to particular persons or organizations. (After Webster 1963)

2. The division of limited resource capacity or supplies among the competitors for use. (C.F.S.)

3. Allocation is necessary when there are limitations on either the amount of resources available or on the way in which they can be used such that each separate activity cannot be performed in the most effective way conceivable. (U.S. Forest Serv. 1972B)

Resource analysis unit (RAU)

U.S. Forest Service Resource Capa-

bility System usage. Broad homogeneous soil-vegetation groupings of the ecological land units (ELU).

The RAU may be comprised of a single ELU or a group of ELU's which have been determined by analysis to have similar inventory characteristics and which will react in a similar manner to land management activities at the intensity of analysis being undertaken. (Reid 1972)

Resource area. See **Land resource area.**

Resource bearing capacity. See **Carrying capacity, ecological.**

Resource capability unit

U.S. Forest Service Resource Capability System (RCS) usage. This term has generally been replaced by **ecological land unit**.

See **Ecological land unit**, definition 2.

Resource conservation district. See **Soil conservation district.**

Resource conservation planning

U.S. Soil Conservation Service usage. SCS technical planning assistance to individuals, groups and representatives of units of government concerning the opportunities and problems involved with the use, development, and conservation of soil and water resources.

Such technical assistance may range from providing aid during the entire planning process (as with individuals developing **conservation plans** for units of land) to helping develop resource inventories and interpretations and assisting in their evaluations, analysis and use. It also includes assisting representatives of units of government develop and carry out resource plans for communities, areas or regions. (After Soil Conserv. Soc. Amer. 1970)

Resource depletion. See **Depletion.**

Resource, extrinsic. See **Extrinsic resource.**

Resource, intrinsic. See **Intrinsic resource.**

Resource Management System (RMS)

U.S. Soil Conservation Service usage. A combination of interrelated conservation, practices and management techniques used to maintain or improve soil, water, plant and related resources. The system is designated according to primary use. (*J.H.H.*)

Resource plan

U.S. Soil Conservation Service usage. A plan prepared by a unit(s) of government and used as a guide for public policy and action on the use, treatment, and management of soil and water resources. Resource plans are generally parts of **comprehensive plans** or **functional plans**. (*U.S. Soil Conserv. Serv. 1970*)

Resource region. See **Land resource region.**

Resource scarcity. See **Economic scarcity.**

Resources Planning Act. See **Forest and Rangeland Renewable Resources Planning Act.**

Resource Unit. See **Land resource unit.**

Response form

Federal Executive Branch usage. A form not needing prior approval of the Office of Management and Budget (OMB), which is provided by a government agency to allow interested members of the public to comment on an agency action or publication. To qualify as a "response form" the form must be distributed only to those members of the public who have requested informational material or are directly affected by possible management actions. The form may include (A) name, address, and organizational affiliation of respondent, (B) a brief description distinguishing alternative actions and space where the respondent may express comments on the alternatives, and (C) chapter headings listed for respondent comments to aid

in review. It may not contain any other questions relative to the nature or attitudes of the respondent. Any form eliciting public comment which does not meet all of these criteria is a **questionnaire** and when issued by an office of the federal executive branch to ten or more people must have prior approval of OMB. (*After U.S. Forest Serv. Wash. Off. 1974*)

Also see **questionnaire.**

Response unit. See **Homogeneous response unit** and **Ecological land unit.**

Rest-rotation grazing. See **Grazing, rest-rotation.**

Retention

The amount of precipitation on a drainage area that does not escape as **runoff**. It is the difference between total precipitation and total runoff. (*Soil Conserv. Soc. Amer. 1970*)

Revegetation

The reestablishment and development of a plant cover. This may take place naturally through the reproductive processes of the existing **flora** or artificially through the direct action of man—e.g., **afforestation**, range reseeding. (*Ford-Robertson 1971*)

Revenue-cost analysis

A method of comparing alternatives by analyzing the monetary income each alternative would generate in relation to its cost. (*E.C.T.*)

Also see **Benefit-cost analysis** and **Cost-effectiveness analysis.**

Reverse condemnation. See **Condemnation, reverse.**

Right-of-way

In its strict meaning, it is the right of passage over another man's ground; and in its legal and generally accepted meaning, in reference to a roadway, it is a mere **easement** in the lands of others, obtained by lawful condemnation for public use or by purchase. It is unusual to use the term to apply to an

absolute purchase of the **fee simple ownership** of land to be used for a roadway or other kind of way.

“Right-of-way” has two-fold significance being sometimes used to mean the mere intangible right to cross, and often used to otherwise indicate that strip of land upon which a road is built. (*U.S. Bur. Outdoor Recreation 1974*)

Rights, mineral. See **Mineral rights**.

Rights, subsurface. See **Mineral rights**.

Rights, surface. See **Surface rights**.

Rill erosion. See **Erosion, rill**.

Riparian

1. In loose usage, referring to the land bordering a stream, lake or tide-water. (*Hanson 1962*)

2. Of, pertaining to, or situated on the banks of a river (though by common usage extended to include any stream, irrespective of size). (*Stamp 1961*)

Also see **Littoral**.

Riparian rights

1. The rights of owners of lands on the banks of watercourses or bodies, relating to the water, its use, ownership of soil under the stream, shoreline accretions, etc. (*U.S. Bur. Outdoor Recreation 1974*)

2. The rights accruing to a landowner on the bank of a natural watercourse, lake, or ocean. These rights vary with state law. Riparian rights cease at the water's edge and do not interfere with use of the water area by others offshore. (*After Abrams 1971*)

Risk

1. **Uncertainty** in a situation is characterized as risk if it is possible to describe all possible outcomes and to assign meaningful, objective, numerical, probability weights to each one.

For example, an action might lead to this risky outcome: a reward of \$10 if a “fair” coin comes up heads, and a

loss of \$5 if it comes up tails. (*After U.S. Forest Serv. 1972B*)

Under the Bayesian school of thought the distinction between “risk” and **uncertainty** is not useful and in fact may not exist. In any practical analysis all uncertain situations are assigned probability distributions, either explicitly or implicitly by the selection of the analysis method. Whether or not the true probability distribution is known, a probability distribution is selected for analysis purposes based on experience, intuitive feelings, knowledge, and the lack of knowledge. (*E.C.T.*)

2. The possibility of loss, injury, disadvantages, or destruction. (*Webster 1963*)

Also see **Uncertainty**.

Risk, acceptable

The level of **risk** (see definition 2) below which no specific action by local government is deemed necessary, other than making the risk known. (*Calif. Counc. on Intergov. Relat. 1973*)

Risk, avoidable

Risk (see definition 2) not necessary to take because the individual or public goals can be achieved at the same or less total “cost” by other means without taking the risk. (*Calif. Counc. on Intergov. Relat. 1973*)

Risk cutting

Cutting to remove trees that are likely to die before the next periodic cut. (*U.S. Forest Serv., FSM 2471R-3*)

Risk, unacceptable

The level of **risk** (see definition 2) above which specific action by government is deemed necessary to protect life and property. (*Calif. Counc. on Intergov. Relat. 1973*)

River basin. See **Watershed**.

River basin plan (Regional plan, Level B plan, Type II plan)

1. One of the "levels of planning" for water and related land resources planning by Federal agencies whose activities involve planning and development of water resources as contained in the **Principles and Standards** of the U.S. Water Resources Council.

"Regional" or "river basin plans" are reconnaissance-level evaluations of water and land resources for selected areas and are performed under planning authorities of Public Law 83-566 and Public Law 87-639. They are directed toward resolving the complex problems identified by **framework studies and assessments** or other Federal-state investigations and terminate in a recommended plan or disclosure of possible alternative plans. They may vary widely in scope and detail; will consider present and long-range problems with a focus on middle term (15 to 25 years) needs and desires; and will involve interested Federal, state, and local entities.

Regional or river basin plans are concerned with a broad array of component needs of objectives. Alternate plans will consider effects on many components of objectives. Scheduling for implementation of the recommended plan or alternative plans will be presented to indicate the relationship to needs and the urgency or priority associated with meeting the needs. (*U.S. Dep. of Agric. 1974*)

2. A plan for development of water and related land resources to make the best use of such resources to meet the basin needs and make the greatest long-term contribution to the economic growth and social well-being of the people of the basin and the nation. (*Soil Conserv. Soc. Amer. 1970*)

River basin planning

Comprehensive planning where the planning unit is defined by the natural boundaries of a river basin. (*E.C.T.*)

Also see **Comprehensive planning** and **River basin plan**.

Roadless and undeveloped areas

A portion of a National Forest larger than 5000 acres, or smaller than this but contiguous to designated wilderness or **primitive areas**, which contains no roads and has been inventoried by the Forest Service for possible inclusion in the wilderness areas system. By management directive these areas were not to be developed until a determination was made on an individual basis whether the area should be considered as a possible wilderness area. (*After U.S. Forest Serv., FSM 8261.05, Apr. 1974*)

Also see **Wilderness study area**, **Nonselected roadless area**, and **Wilderness**, definition 2.

Rock, igneous

Rocks formed by solidification from a molten or partially molten state—e.g., various types of lava.

This class of rock types is often subdivided, for convenience, into "plutonic rocks" (those which were formed by the solidification of molten materials below the ground surface—e.g., granite) and "volcanic rocks" (those formed by solidification of molten materials which have been extruded onto the ground surface. (*After Amer. Geol. Inst. 1962*)

Also contrast with the other two main classes of rock—**Rock, metamorphic** and **Rock, sedimentary**.

Rock, metamorphic

Rocks which have been formed in the solid state under the conditions of high pressure, high temperature and the introduction of new chemical substances that, in general occur at great depths within the earth—e.g., slate, marble, jade. (*After Amer. Geol. Inst. 1962*)

Also contrast with the other two main classes of rock—**Rock, sedimentary** and **Rock, igneous**.

Rock, plutonic. See **Rock, igneous**.

Rock, sedimentary

Rocks which have been formed from deposits of **sediment**—whether from fragments of other rock transported from their sources and deposited by water—e.g., sandstone or shale—or by precipitation from solution or fixation by organisms—e.g., rock salt, gypsum, limestone. (*After Amer. Geol. Inst. 1962*)

Also contrast with the other two main classes of rock—**Rock, metamorphic** and **Rock, igneous**.

Role. See **Social role**.

Rotation (Cutting rotation, Felling rotation, Cutting cycle, Cutting interval)

1. The period of years between the initial establishment of a stand of timber and the time when it is considered ready for cutting and regeneration. (*U.S. Forest Serv. 1972A*)

2. The planned, recurring lapse of time between successive major **cutting** operations in a managed forest. (*After Ford-Robertson 1971*)

Sacrifice area

1. A relatively small area of land in a grazing unit that may still be overused after practical measures for securing uniform grazing distribution have been installed. (*Soil Conserv. Soc. Amer. 1970*)

2. A portion of the range, irrespective of site, that is intentionally overgrazed to obtain efficient overall use of the management area. (*Amer. Soc. Range Manage. 1964*)

Sacrifice site

Range management usage. A **range site** which is intentionally overgrazed to obtain efficient overall use of the management area. (*Amer. Soc. Range Manage. 1964*)

Salvage cutting

1. Cutting primarily to utilize dead and downed material and scattered

Rotational deferment

Range management usage. A grazing system in which one or more parts of the range are rested during the growing season each year; and rotational use of other segments of the range are not necessarily planned for. (*Amer. Soc. Range Manage. 1964*)

Rotation grazing. See **Grazing, rotation**.

Rotation pasture. See **Pasture, rotation**.

RPA. See **Forest and Rangeland Renewable Resources Planning Act**.

Runoff

1. The total stream discharge of water, including both surface and subsurface flow, usually expressed in **acre feet**. (*Amer. Soc. Range Manage. 1964*)

2. The rate at which water is discharged from a drainage area, usually expressed in cubic feet per second per square mile of drainage area. (*Amer. Soc. Range Manage. 1964*)

S

poor-risk trees that will not be merchantable if left in the stand until the next scheduled cut. (*U.S. Forest Serv., FSM 2471.33, June 1973*)

2. The exploitation of trees that are dead, dying, or deteriorating (e.g., because overmature or substantial damage by fire, wind, insects, fungi or other injurious agencies) before their timber becomes worthless. (*Ford-Robertson 1971*)

Sand

1. Particle size usage. Inorganic particles between 0.05 (or 1/16) and 2.0 millimeters in diameter. (*Soil Conserv. Soc. Amer. 1970 and Amer. Geol. Inst. 1962*)

2. "Soil texture" usage. Soil material that contains 85 percent or more sand and a percentage of **silt** plus 1.5 times the percentage of **clay** that does

not exceed 15. (*After Soil Conserv. Soc. Amer. 1970*)

Sanitary landfill

A site where solid waste materials are disposed of on land—supposedly in a manner which prevents their escape into—or pollution of—the surrounding environment. The waste is spread in layers, then compacted to the smallest practical volume and covered with compacted soil at the end of each working day. (*After SESCO, et al. 1973*)

Sanitation cutting

The removal of dead, diseased, infested, damaged, or susceptible trees essentially to prevent the spread of pests or pathogens and so promote forest hygiene. (*After Ford-Robertson 1970*)

Sapling

A loose term for a young tree greater than a few feet tall and an inch or so in diameter at breast height and typically growing vigorously and without dead bark or more than an occasional dead branch. Many countries set arbitrary size limits—2 to 4 inches diameter at breast height in the United States. (*Ford-Robertson 1971*)

Satisficing

A method of choosing among alternatives. Minimum values or quality standards are established for all attributes affected by the alternatives. All those alternatives which do not meet the minimum requirements are eliminated from consideration. By successively raising the minimum requirements you can successively reduce the number of alternatives under consideration. (*After Mac Crimmon 1968*)

Scale

1. Graphics usage. The proportional relationship (ratio) between the reduced size at which something is being represented on a map or other type of drawing and its true distance or size relationships. (*C.F.S.*)

2. Aesthetics of proportions usage. A feeling for the size and/or appropriateness of the size of some construction element (i.e., a building, paved area, etc.) or project. (*C.F.S.*)

Also see **Sense of scale** for a more extensive discussion of this usage of “scale”.

Scarcity. See **Economic scarcity.**

SCD. See **Soil conservation district.**

Scenario

1. A hypothetical sequence of future events constructed for the purpose of focusing attention on causal processes and decision points. (*After Kahn and Wiener 1967*)

2. “Scenarios” express a series of integrated objectives for preserving the environment, the fulfillment of which is dependent upon timing as an “urgency” rather than as a “sequence”. For example, some strategic natural areas that may be shown on scenarios actually exist on the ground today, but will not be found anywhere in the year 2000 unless they are reserved now. (*Hills, Love and Lacate 1970*)

3. A word picture of a fixed sequence of future events in a defined environment. (*U.S. Forest Serv. 1972B*)

Scenic area

1. U.S. Forest Service usage. A place which has been designated by the Forest Service as containing outstanding or matchless beauty which requires special management to preserve these qualities. (*U.S. Forest Serv., FSM 2362.41, June, 1974*)

Areas of this type and all other **special interest areas** are identified and formally classified primarily because of their recreational values. (*W.W.*)

2. An area preserved primarily because of its present beauty, such as cliffs, streams, vistas, vegetation, and wildlife. (*U.S. Bur. Outdoor Recreation 1974*)

Scenic corridor

The visible land area outside the highway **right-of-way** and generally described as "the view from the road". (*Calif. Counc. on Intergov. Relat. 1973*)

Scenic easement. See **Easement, scenic.**

Scenic river

Wild and Scenic Rivers Act usage. Those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely **primitive** and shorelines largely undeveloped, but accessible in places by roads. (*After U.S. Forest Serv. 1974*)

Schematic diagram. See **Diagrammatic representation.**

SCS

Soil Conservation Service, U.S. Department of Agriculture.

Secondary effect. See **Indirect effect.**

Secondary facility

Transportation planning usage. Secondary facilities provide access to smaller land areas than **primary facilities**. They are multi-resource oriented, providing access and mobility for the utilization of a variety of resource systems, and are usually developed and operated for long-term service. Emphasis is given to achieving a balance between travel efficiency and resource service. (*U.S. Forest Serv., FSM 7705.42, Aug. 1975*)

Also see **Primary facility** and **Tertiary facility**.

Secondary range

Range which is lightly used or unused by livestock under minimal management and will ordinarily not be fully used until the **primary range** has been overused. (*Amer. Soc. Range Manage. 1964*)

Secondary sewage treatment. See **Secondary wastewater treatment.**

Secondary succession. See **Succession, secondary.**

Secondary treatment. See **Secondary wastewater treatment.**

Secondary use (Accessory use)

A use incidental, related, appropriate, and clearly subordinate to the main use of an area, lot or building. An accessory use does not alter the principal use of the subject lot or affect other properties in the zone. (*Eisner 1969*)

Also see **Dominant use** as a contrasting position in the use allocation hierarchy to **secondary use**.

Secondary wastewater treatment (Secondary treatment, Secondary sewage treatment)

1. Any process that takes the effluent from **primary wastewater treatment** and reduces the **suspended solids** and **biological oxygen demand** by approximately 90 percent. During secondary treatment, the wastewater is subject to biochemical action, increased sedimentation, and clarification. (*Sesco et al. 1973*)

2. This wastewater treatment uses biological methods (primarily bacterial action) in addition to the primary treatment's removal of most floating and suspended solids by screening, sedimentation and floatation. In secondary treatment biodegradation by bacteria is used to destroy organic wastes, commonly by trickling the waste water over coarse stones. The process removes up to 90 percent of the dissolved biodegradable pollutants and 93 percent of the **suspended solids** from wastewater, but leaves many other pollutants untouched. (*Wash. State Univ., Coop. Ext. Serv. 1972 and Mc Gauhey 1968*)

Second growth

Forest growth that has come up naturally after some drastic interference (e.g., wholesale cutting, serious fire, or insect attack) with the previous forest crop. (*Ford-Robertson 1971*)

Sediment

Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level. (*Soil Conserv. Soc. Amer.* 1970)

Sedimentary rock. See **Rock, sedimentary.**

Sediment discharge

The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both **suspended load** and **bedload**. (*Soil Conserv. Soc. Amer.* 1970)

Sediment load. See **Sediment discharge.**

Seed tree

1. A tree purposely left standing at the time of cutting in a forest, for the purpose of producing seed for regeneration of trees in the cut-over area. (*Hanson 1962*)

2. A tree selected, and often reserved, to be a source of seed for collection. (*Ford-Robertson 1971*)

Seed tree cutting (seed cutting)

1. Removal in one cut of the mature timber from an area, save for a small number of seed bearers left singly or in small groups. (*Ford-Robertson 1971*)

2. A **regeneration cutting** where the planned source of the new stand is from seed existing on, or to be produced by, trees standing on the cut-over area.

The cutting removes all the mature timber except for the number of seed trees which are needed to provide seed for reproducing the stand. (*U.S. Forest Serv., FSM 2471R-3*)

Cutting which leaves the number of seed trees needed to provide the optimum amount of seed required to re-

stock, but not overstock, the area. (*U.S. Forest Serv., FSM 2471.22, June, 1973*)

See **Shelterwood system** for the timing relationships between this cutting type and others in that silvicultural system.

Seed tree removal cutting

Cutting made to remove the seed trees when adequate reproduction above browse height has been established. (*U.S. Forest Serv., FSM 2471R-3*)

Seismic

Pertaining to or caused by an earthquake. (*Calif. Counc. on Intergov. Relat.* 1973)

Seismic hazards

Hazards related to seismic or earthquake activity. (*Calif. Counc. on Intergov. Relat.* 1973)

Selection cutting. See **Selection logging.**

Selection logging (Selection cutting)

Removal of mature timber, usually the oldest or largest trees, either as single scattered trees or small groups at relatively short intervals, commonly 5 to 20 years, repeated indefinitely, by means of which the continuous establishment of natural reproduction is encouraged and an **uneven-aged stand** is maintained. (*Ford-Robertson 1971*)

Selection system

An **uneven-aged silvicultural system** in which trees are removed individually, here and there, from a large area each year.

Regeneration is mainly natural and the timber crop ideally all different ages. (*Ford-Robertson 1971*)

Selective grazing. See **Grazing, selective.**

Selective logging. See **Selection logging.**

Selectivity

Range management usage. The degree to which a plant or plant part is removed differently from that which is

expected by random removal. Selectivity is expressed as the ratio of the proportion of a plant or plant part in a diet to all the other herbage. (*H.F.H.*)

Also see **Palatability**.

Sense of community. See **Human community**, definition 2.

Sense of scale

A feeling for the size and/or appropriateness of the size of some project or construction element (i.e., building, paved area, etc.).

An evaluation of the sense of appropriate size (or mass) relationship of some design material, element, or object to its surroundings, its intended use or user group, etc. For example, the use of brick as a building material is sometimes said to result in constructions of a "human scale"—because people have a strongly developed awareness of the size of individual bricks, and therefore, can sense the size of buildings or paved areas by using the individual brick as the basis of judgement. In contrast, because concrete can be poured into almost any size units, people can have difficulty correctly judging the size of objects made out of concrete. In a similar sense, entire large highrise (i.e., multi-storied) buildings may be described as being out-of-scale when placed in surroundings dominated by 2- or 3-story buildings. (*C.F.S.*)

Sensitivity analysis

1. Varying the value of the parameter or parameters in question and examining the extent to which these changes affect the results of the analysis. (*U.S. Gen. Account. Off. 1969*)

2. Repetition of an analysis with different quantitative values for the variables in order to determine their effects on the results of the basic analysis.

If a small change in an assumption results in a proportionately greater change in the results, then the results

are said to be "sensitive" to that assumption or parameter. (*U.S. Forest Serv. 1972B*)

Sensitivity, land

The degree to which the land cannot sustain or heal itself from externally imposed disturbance or land uses. (*Sandpoint Zone Plann. Team 1973*)

Also see **Fragility** and **Fragile land** for very similar concepts.

Sensitivity level. For U.S. Forest Service usage see **Visual sensitivity level**.

Seral

A biotic community which is a developmental, transitory stage in an ecologic succession. (*Carpenter 1938*, citing *Phillips 1930*)

Sere

1. The series of stages that follow one another in an ecologic succession. (*Hanson 1962*)

2. The series of biotic communities that follow one another in time on any given area of the earth's surface. (*Carpenter 1938*)

Also see **Succession**, definition 1.

Servient

The land against which an easement or privilege exists is called the "servient" tenement and the estate to which it is annexed is the dominant tenement. Their owners are respectively the servient and dominant owners. (*U.S. Bur. Outdoor Recreation 1974*)

Also see **Easement**.

Sheet erosion. See **Erosion**, sheet.

Sheet flow. See **Overland flow**.

Shelterwood cutting

Cutting which leaves enough trees to provide about half shade or more on the ground. In some places, more trees than are needed to provide shade for reproduction must be left in order to prevent windthrow. (*U.S. Forest Serv., FSM 2471.22, Jan. 1974*)

See **Shelterwood system** for the

timing relationships between this cutting type and others in that silvicultural system.

Shelterwood system

Even-aged silvicultural systems in which (in order to provide a source of seed and/or protection for regeneration) the old crop is removed in two or more successive "shelterwood cuttings", the first of which is ordinarily the **seed tree cutting** and the last is the **final cutting**, any intervening cuttings being termed **removal cuttings**. (*Ford-Robertson 1971*)

Short-range planning

1. Planning for a future less than 5 years distant. (*U.S. Forest Serv. 1972B*)

2. U.S. Forest Service usage. Information use for planning and control for the period covered by specific **action plans**—i.e., **functional plans**. (*U.S. Forest Serv. 1972B*)

Shrink-swell potential

The susceptibility for a soil's volume to change due to loss or gain in moisture content. (*Soil Conserv. Soc. Amer. 1970*)

Silt

1. Particle size usage. Fragments of rock or organic matter **sediment** most of the individual particles of which are between 1/16 and 1/256 millimeters in diameter. (*Amer. Geol. Inst. 1962*)

Soil particles which are between 0.05 and 0.002 millimeters in equivalent diameter. (*Soil Conserv. Soc. Amer. 1970*)

2. "Soil texture" usage. A **soil texture** type consisting of 80 percent or more of silt particles and less than 12 percent **clay** particles. (*After Soil Conserv. Soc. Amer. 1970*)

Silvics

The natural science which deals with the laws underlying the growth and development of single trees and of the forest as a biological unit. (*Smith 1962*)

Silviculture

1. Generally, the science and art of cultivating (i.e., growing and tending) forest crops, based on a knowledge of **silvics**. (*Ford-Robertson 1971*)

2. More particularly the theory and practice of controlling the establishment, composition, constitution, and growth of forests. (*Ford-Robertson 1971*)

3. In imprecise usage, **cutting**, **logging**, **harvesting**, and "silviculture" are used seemingly interchangeably by different people, often with vehemence as to which is the correct term in a given situation. According to Ford-Robertson (1971) "silviculture" has as its primary concern the establishing, growing, and tending of forests. "Harvesting" and "logging", however, deal specifically with the extraction of resources from the forest; with "logging" restricted to the felling and extraction of timber (wood other than fuel wood after **primary conversion**), whereas "harvesting" expands this to include the cutting, initial processing if any, and extraction of any forest product. "Cutting" refers only to the actual felling of standing trees. (*After Ford-Robertson 1971*)

Simulation

1. An abstraction or simplification of a real world situation. In its broadest sense any **model** is a simulation, since it is designed to represent the most important features of some existential conditions. (*U.S. Gen. Account. Off. 1969*)

2. Use of a model to determine results under specific sets of circumstances. (*After U.S. Gen. Account. Off. 1969*)

3. A technique for solving complex problems that are not amenable to solution using formal analytical techniques. Essentially simulation consists of a representation of a system or organization by means of a model. The behavior of the system under various

possible operational conditions is then analyzed through repeated manipulation of the model. (*U.S. Forest Serv. 1972B*)

Sink

In pollution terminology, any location where wastes are or ultimately become deposited—as in underground burial places, in underwater deposits, in ocean water, etc. (*After SESCO, et al. 1973*)

Site

1. City planning and environmental design professions usage. A plot of land intended or suitable for development.

The ground or area upon which a building or town has been erected. (*Abrams 1971*)

2. Forestry usage. An area considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can inherently produce.

“Sites” are classified either qualitatively, by their climate, soil and vegetation, into **site types**, or quantitatively, by their potential wood production, into **site classes**. (*Ford-Robertson 1971*)

Site capacity

U.S. Forest Service usage. The number of persons who may, at one time, use the developed capacity (i.e., **facility carrying capacity**) of a location while not exceeding the safe, season-long carrying capacity (i.e., **ecological carrying capacity**) per acre.

The inherent capacity of a resource area to support use without unacceptable damage (i.e., “ecological carrying capacity”). (*After U.S. Forest Service, FSM 2331.110, Oct. 1967*)

Site class (**Locality class, Productivity class, Quality class, Growth class, Yield class**)

A quantitative measure of the productive capacity of an area which is

essentially uniform with respect to those factors controlling productivity for the crop or stand under study. The quantitative measure is based on the volume, height or maximum mean annual increment that is attained or attainable on that area at a given crop age. (*After Ford-Robertson 1971*)

Site design. See **Site planning**.

Site index

1. A numerical evaluation of the quality of land for plant productivity especially used in **forest land** where it is determined by the rate of growth in height on one or more of the tree species. (*Hanson 1962*)

2. A particular measure of **site class**, based on the height of the dominant trees in a stand at an arbitrarily chosen age. (*Ford-Robertson 1971*)

Site plan

A plan, prepared to scale, showing accurately and with complete dimensioning, all of the buildings, structures and uses and the exact manner of development proposed for a specific parcel of land. (*Eisner 1969*)

Site planning (**Site design**)

The organization of the external physical environment up to the largest scale at which it can still be subject to unified and complete control. It deals with structures, land and the entire complex of physical forms above and below and on the surface. It has at its heart the disposition of objects and activities in 3-dimensional space. It begins with the careful analysis of the project site and purpose; and, it concludes with design of a pattern which interacts as a totality with its users and which is subject to continuous future development and change.

“Site planning” produces a plan which can be carried out in one continuous foreseeable process, according to one original design, under the control of one agency, inclusive of all de-

tails of site engineering, landscaping, and architecture.

"Site planning" may take place on areas as small as a single building and its grounds, or as large as the layout of a complete small town. (*Lynch 1962*)

"Site planning" is the smallest level at which "land use planning" is done.

In some instances "site planning" can almost be a synonym for **project planning**. The main difference usually is that "site planning" is more concerned with the specifics of the design aspects of site use—e.g., site circulation, optimum relationships between project components on the site, placement of structures and other changes in relation to any inherent site limitations or potentials, the aesthetics of site use, maintenance of some sense of continuity with surroundings, etc. Those portions of "project planning" which are concerned with the design aspects of site use are sometimes called the "site planning" phase of "project planning". However, "project planning" typically involves many additional considerations which are not within the scope of site planning—such as economic studies of markets and location, optimum organization of facilities within buildings, etc. (*C.F.S.*)

ite quality

A loosely used term denoting the relative productivity of a site for a particular tree species. (*Ford-Robertson 1971*)

Also see **Site class** and **Site index**.

ite region

G.A. Hills land classification usage. The subdivision of a region on the basis of broad **macroclimatic** similarities—such as cool humid vs. warm humid.

Broad areas where air temperature and relative humidity generally correspond to similar landform and vegetation **succession**. Site regions vary in size from 1000 to 4000 square miles

and often form administrative and management units. (*After Belknap and Furtado 1967*)

The largest unit in Hills' land classification system. The various levels, in order of decreasing size, are **Site region**, **Landtype**, **Physiographic site class**, **Physiographic site type** and **Physiographic site phase**.

Site specific

In "land use planning" usage this term commonly refers to something only valid for, or confined to, a certain given parcel of land and/or water. The term may apply to data, studies to obtain information, environmental impacts, use restrictions, etc.

The assumption is that mapped land characteristics are, in varying degrees, generalizations about a true distribution of characteristics. Such appropriate-use-affecting generalizations cannot be assumed valid for every parcel of land contained within the larger mapped units. "Site specific" studies may be needed to confirm or change the appropriate land use classification of a particular parcel.

"Site specific" implies limitations on transference or extrapolation of observations beyond a specific parcel of land, while **geographic specific** implies the same limitations with respect to relatively large blocks of land of unspecified ownership. (*C.F.S.*)

Site type

A biotic productivity unit (usually for trees) which is qualitatively defined on the basis of being relatively uniform with respect to climate, soil and natural vegetation cover. (*After Ford-Robertson 1971*)

For quantitative productivity classifications see **Site class**.

Also see **Site**, definition 2.

Skidding

A loosely used term for the transportation of logs from stumps to a collecting point by sliding or dragging

along the ground—as opposed to the use of wheels, helicopters, balloons, cables, etc., to keep them totally off the ground.

The logs may slide more or less wholly along the ground or with their forward end supported. (*After Ford-Robertson 1971*)

Sometimes the term “skidding” is even used to refer to log transportation methods which keep them wholly off the ground during their main journey (especially when sliding logs along a cable as in “aerial skidding”) but this usage is clearly in conflict with the central concept, and therefore, should be discouraged. (*C.F.S.*)

Skyline logging. See **Logging, skyline.**

Skyline yarding. See **Yarding, skyline.**

Slash

The residue left on the ground after timber cutting and/or accumulating there as a result of storm, fire or other damage. It includes unutilized logs, uprooted stumps, broken or uprooted stems, branches, twigs, leaves, bark and chips. (*Ford-Robertson 1971*)

Slope

An inclined portion of the surface of the earth. (*Amer. Geol. Inst. 1962*)

Also see **Slope orientation** and **Slope steepness.**

Slope gradient. See **Slope steepness.**

Slope orientation (Aspect, Exposure)

The compass direction that the slope of a land surface faces toward (e.g., north, northwest, south). (*After Soil Conserv. Soc. Amer. 1970*)

Slope stability (Mass instability)

An evaluation (almost always qualitative and expressed as a probability) of the tendency for the materials on or constituting a slope (e.g., rocks, soil, snow) to either remain in place or to move downhill. (*C.F.S.*)

Also see **Landslide hazard, Snow avalanche hazard.**

Slope steepness (Slope, Slope gradient, Slope inclination)

The degree of deviation of a land surface from the horizontal—usually expressed in percent (i.e., amount of elevation change per 100 feet, expressed as a percentage) or degrees. (*After Soil Conserv. Soc. Amer. 1970*)

SMSA. See Standard metropolitan statistical area.

Snag

1. A standing dead tree from which the leaves and most of the branches have fallen. (*Ford-Robertson 1971*)

2. A standing section of the stem of a tree broken off at a height of 20 or more feet above the ground. (*Ford-Robertson 1971*)

Snow avalanche

The rapid downslope movement of large quantities of snow. (*Amer. Geol. Inst. 1962*)

Snow avalanche hazard (Snowslide hazard)

Some evaluation (almost always qualitative and relative to adjacent locations) of the chance that a **snow avalanche** will occur on a given site. (*C.F.S.*)

Snowslide. See **Snow avalanche.**

Social analysis

1. An analysis of the social (as distinct from the economic and environmental) effects of a given plan or proposal for action. Social analysis includes identification and evaluation of all pertinent desirable and undesirable consequences to all segments of society, stated in some comparable quantitative terms—such as persons or percent of population in each affected social segment. It also includes a subjective analysis of social factors not expressible in quantitative terms. (*C.F.S.*)

For example, “social analysis” would include effects on life styles,

the political process, education, health care, housing, distributions of power and income, and the quality of public services. (*E.C.T.*)

2. A phase in the planning process which (1) identifies groups (whether formally organized as groups or not) who may be affected by or have an interest in planning decisions; (2) gathers and quantifies (objectively when possible) both the preferences of these groups and the possible consequences of proposed alternatives on these groups; (3) evaluates the role of social group preferences and consequences in resource allocation decisions; and (4) determines how a given plan should be formulated (or adjusted) so as to respond to these evaluations and to generally defined **social equity** criteria.

"Social analysis" is a part of both the plan formulation and impact evaluation processes.

The determination of the best method(s) for obtaining the desired information from representative samples of each social group and the collection of that information usually involves use of such survey research procedures as: **questionnaire** design, distribution and retrieval; conducting polls; holding public hearings; forming ad hoc task forces and advisory groups; and conducting behavioral studies.

The determination of how to evaluate the various social groups' diverse (and often conflicting) preferences for allocation choices usually consists of some systematic method for establishing the relative importance of the various social groups and expressing this as **multipliers** or **weightings**.

Establishing how social groups' attitudes, use behavior characteristics, etc. could be reflected in future planning decisions, or how plan decisions which have already been made could be altered so as to better respond to these kind of considerations includes

the evaluation of the extent to which different social groups will be benefited or harmed by any decision that may be made. This usually involves making some hard decisions about balancing the net gains in the **quality of life** for some groups against the gains and losses of others.

In the end, the findings and guidance developed by the "social analysis" process are combined (compromising where necessary) with the analogous findings and guidances originating from analysis of economic, ecological, amenity, and other decision making considerations to arrive at an overall set of plan guiding and/or evaluative criteria. (*C.F.S. and E.C.T.*)

Social benefits

1. The net benefit considerations of long-range societal values at the regional or national level which might not be taken into account in the profit and loss statement of an individual farmer, forest operator, industrialist or other private citizen. (*Wash. State Univ., Coop. Ext. Serv. 1972*)

Note that this term in economic usage does not include the profit and loss statements of such legally defined individuals as corporations. Their profits and losses are assumed to appear in the statement of single individuals.

In common usage "social benefits" is often used when referring to the externality benefits (see **economic externalities**) accruing to groups of individuals or to society as a whole. (*C.F.S.*)

2. The non-monetary and rarely quantifiable returns to society arising from any form of economic activity—e.g., those recreational benefits resulting from the creation of a scenic overlook. (*Ford-Robertson 1971*)

Social carrying capacity. See **Carrying capacity**, **psychological**.

Social class

1. In its simplest usage, merely a category of people who have been

grouped together on the basis of one or more common characteristics. The characteristics can usually be viewed as **hierarchical**. Basically, then, a class stratum in a hierarchically stratified social structure.

Disputes about a more precise definition of "social class" revolve around two issues—the choice of the factors by which a population is classified, and whether or not a class must have grouplike features in addition to the objective similarities that its members share. Classes are viewed by some sociologists as quasigroups (that is, categories with some grouplike characteristics) or statistical aggregates. (*O'Connell 1974*)

2. The most common usage of "class" implies a definition in terms of categories that share relatively equal amounts of economic, prestige, and political-power resources.

The factors according to which a society may be stratified into classes fall into three broad categories—economic, social, and political.

Economic factors used to define classes include: (1) relationship to the means of production (i.e., basically, ownership or nonownership of capital), (2) similarity of market positions (whether they may or may not have developed a sense of commonality), or most commonly, (3) aggregates of individuals sharing similar amounts of income or wealth.

Social factors used to define classes include **differential life styles (subcultures)**, **prestige** or the clustering of interaction patterns.

Political factors used to define social class structure include (1) the relationship to the means of force and government (viewing political control as not solely dependent on economic control), (2) defining classes as conflict groups (comprised of those with and those without authority) which develop inevitably in any association

or society with a hierarchical command structure, and (3) aggregates of persons in similar power position (with the basic sources of power being force, position, occupation and property).

In many empirical studies "social classes" are defined as socioeconomic categories on the basis of two or more objective hierarchical indicators (for example, income, occupation, education). (*O'Connell 1974*)

Social costs

1. The net loss considerations of long-range societal values at the regional or national level which might not be taken into account in the profit and loss statement of an individual farmer, forest operator, industrialist or other private citizen. (*Wash. State Univ., Coop. Ext. Serv. 1972*)

Note that this term in economic usage does not include the profit and loss statements of such legally defined individuals as corporations. Their profits and losses are assumed to appear in the statements of single individuals.

In common usage social cost is often used when referring to the externality costs (see **economic externalities**) accruing to groups of individuals or to society as a whole. (*C.F.S.*)

2. The non-monetary and rarely quantifiable losses to society arising from any form of economic activity—e.g., from air pollution whose only deleterious side effect is reduced visibility, over and above the expenditures for the goods and services causing the smoke. (*Ford-Robertson 1971*)

Social determinism (Social primacy)

1. A point of view in planning which advocates that the primary basis for making use and allocation decisions should be satisfaction of current societal demands on resources. The ability of the resource base to sustain such demanded use levels on a long term basis is not recognized as an im-

portant criterion for decision making by the social primist. (*C.F.S.*)

2. Sociological usage. The belief that human behavior is produced by conditions in the social world. In this view, when a person is born, he is essentially unmarked, a clean surface. His potential for good or evil, success or failure, or the various states in between, will be decided by the social environment, which is formed by his family, his friends, his work associates, and overlaying all of these groups, the culture. Sociologists are basically "social determinists". (*O'Connell 1974*)

Social distance

1. Environmental psychology usage. The distance maintained by animals and persons based on the social situation involved. "Social distance" is a psychological distance which is not rigidly fixed, but shifts with the situation and varies from species to species. (*After Worthington 1974*)

2. Presuming that people are conscious of having a certain "place" in a social hierarchy and, further, that they are conscious of the places of others, the differences between the respective places is "social distance". For example, the social distance between a physician and a garbage collector will probably be greater than that between the physician and a car salesman.

Occupational status is only one component of "social distance"; others will be relevant to the situation in which the individuals find themselves. For example, on a ski slope, occupation may mean little and skiing ability may be the essential determinant of social distance. Social distance will also vary with the extent to which the two people know each other. On first encounter the determinants of social distance will include appearance, mode of self-introduction, and attributes of social status such as occupational prestige. As the relationship develops, these factors may become less

important, and others, such as intelligence, will enter into the determination of social distance. (*O'Connell 1974*)

Also see **Social role**.

Social dynamics

The forces and processes involved in social change. The processes of interaction leading to change may involve economic, political, ideological, individual, or other variables.

Some theorists see this dynamic as a dialectical one, involving a succession of conflicts and their resolutions. Others see the dynamic as a developmental, cumulative process in which conflict is merely incidental. (*O'Connell 1974*)

Social engineering

Application of sociological principles to problems of society. (*O'Connell 1974*)

Social equity

The distribution of the gains and losses that will accrue to individuals or groups (defined according to social criteria), as a consequence of land use planning decisions, in a manner which is in reasonable conformity to accepted standards of natural rights, law and justice, without prejudice, favoritism or fraud and without causing undue hardship. (*C.F.S.*)

Social group

Generally, an aggregate of people present in some sort of situation involving their interaction with one another. A group may consist of almost any number of people, and the interaction may involve the performance of a complex task or simply being together in the same place at the same time.

In any setting the behavior of the individual is determined by being part of the group, though the ways in which such determining occurs will vary with the settings. (*O'Connell 1974*)

Social inequality

A condition in which various members of a society have unequal amounts of income, prestige, and **social power**. (*O'Connell 1974*)

Social institutions. See **Institutions, social**.

Social mobility

The upward or downward movement of individuals or groups into different positions in a social hierarchy based on wealth, income, occupation, education, **social power**, or any other scarce social resources.

A society with a high rate of social mobility and good opportunities for upward social mobility is not **egalitarian** but does maximize opportunities for one individual or group to get more of the society's scarce resources than other individuals or groups can get. (*O'Connell 1974*)

Social mores

The fixed customs or **folkways** of a particular social group that are morally binding upon all members of the group and necessary to its welfare and preservation. (*Webster 1963*)

Social norms

The shared **expectations** of a **social group** or society.

The concept assumes a relationship between the perceptions of shared expectations by members of the social group and the extent to which the **norm** influences behavior. To the degree to which human behavior is influenced by the **normative** content of the culture of one's society, such behavior might be explained in terms of the collective expectations as perceived, shared, and enforced by the group.

Normative variations exist even in a relatively stable culture. These variations are due to the generalized nature of norms relative to specific social situations and to the variations in their perception and interpretation by indi-

viduals. Moreover, in societies such as the United States, whose structure manifests **subcultural** variations, ambiguities and variations concerning the meaning of norms are to be expected.

Norms are external to the individual to the extent that normative definitions exist in the reality defined by a particular culture, which may preexist his being. There is a hierarchy of such definitions of "right and wrong". These are traditionally identified as "folkways", **mores**, and laws. (*O'Connell 1974*)

Also see **Norm**.

Social planning. See **Advocacy planning**.

Social power

The extent to which a person can impose their will on a group. That is a person has power when he gets the members of a group to do what he or she wants, regardless of what they want. (*O'Connell 1974*)

Social prestige

The respect or favorable regard enjoyed by individuals or groups and linked to the **social status** accorded to these individuals or groups. Prestige is frequently, but not necessarily, the result of the possession of power or wealth. (*O'Connell 1974*)

Social primacy. See **Social determinism**.

Social role

Generally, a role consists of those behaviors typically performed by an individual in a particular situation. The individual's assumption of a role implies his acceptance of the need to act in ways that are socially agreed upon as being appropriate in that situation.

To differentiate role from status, a status generally refers to an **institutionalized** role. Thus, statuses often involve occupational or kinship systems—physician, lawyer, factory worker, or father, mother, uncle. Whereas the physician, by virtue of his profes-

sion, enjoys a certain "status", his "role" in any situation will be more fluid. (O'Connell 1974)

Social status

A position based on prestige and life style. Status group members share these characteristics to a similar degree.

It is often useful to consider a society's status hierarchy independently from its social class hierarchy which is based largely on economic position. Status frequently derives from class position, but it may be achieved independently of economic standing. (O'Connell 1974)

Also see **Social class** and **Social power**.

Social well-being

1. U.S. Water Resources Council (WRC) usage. One of the four "required accounts" for categorizing, displaying, or "accounting" the beneficial and adverse effects of each alternative plan formulation for water and related land resources planning specified in the Water Resources Council's **Principles and Standards** and the U.S. Department of Agriculture's "Procedures" for adhering to them. (After U.S. Dep. of Agric. 1974)

2. The "social well-being" account includes (at least): (1) real income distribution among individuals, classes, and groups; (2) life, health, and safety; (3) educational, cultural, and recreational opportunities; and (4) emergency preparedness. (After U.S. Dep. of Agric. 1974)

Soft pesticides. See **Nonpersistent pesticide**.

Soil

1. The loose surface material of the earth, usually consisting of disintegrated rock with an admixture of organic matter and soluble salts. (Webster 1963)

2. Agricultural usages. The collection of natural bodies occupying portions of the earth's surface that support plants and that have properties due to the integrated effect of climate and living matter, acting upon **parent material**, as conditioned by relief, over periods of time. (U.S. Soil Conserv. Serv. 1951)

The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (Soil Conserv. Soc. Amer. 1970)

The unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of **parent material**, climate (including moisture and temperature effects), macro- and micro-organisms, and topography, all acting over a period of time and producing a product—soil—that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics. (Soil Conserv. Soc. Amer. 1970)

According to these definitions "soil" only extends to the depth important for plant growth—operationally defined for the U.S. Soil Conservation Service surveys as the depth to root growth limiting material or a 60 inch depth, whichever is encountered first. (C.F.S.)

In agricultural usage the "soil" is the **solum**.

3. Engineering usages. The layer of loose, incoherent rock material of whatever origin that rests on the hard or **bedrocks**—i.e., the entire **soil profile** down to and sometimes even into the underlying consolidated rocks. (Jumikis 1962)

Note that in this definition the lower boundary between a soil and a non-soil is not defined by root growth-limiting material or the operational 5

foot depth—whichever is encountered first. Spatially the engineer recognizes that there is an ungeneralizable, infinite variety of soils, each with slightly differing physical characteristics while the agricultural soil scientist believes that “soils” can be mapped as significantly homogeneous, discrete units—i.e., **soil types**. (*C.F.S.*)

4. Geological usage. Any loose surface material overlying solid rock.

The **regolith**, or blanket of unconsolidated rock material that lies on the **bedrock**. (*Thrush 1968*)

5. Soils are not simple structures, nor are they static. Each soil is the result of the interactions of the parent materials, the climate, and the vegetation and animal organisms which they support. They respond to environmental changes and to alterations in topography. They can be improved or destroyed. (*Marsh 1964*)

6. A kind of soil is the collection of soils that are alike in specified combinations of characteristics. Kinds of soil are given names in the system of soil classification. (*Soil Conserv. Soc. Amer. 1970*)

Soil and water conservation. See **Conservation**, definition 1.

Soil and water conservation district. See **Soil conservation district**.

Soil association

1. A group of defined and named **soil taxonomic units** occurring together in an individual and characteristic pattern over a geographic region. (*Soil Conserv. Soc. Amer. 1970*)

2. A mapping unit used on **reconnaissance soil maps** or **general soil maps** in which two or more defined taxonomic units occurring together in a characteristic pattern are combined because the scale of the map does not enable (nor does the purpose for which it is being made require) delineation of the individual soils. (*Soil Con-*

serv. Soc. Amer. 1970)

Also see **Soil complex**.

Soil climate

The moisture and temperature conditions existing within the soil. The soil has a **microclimate** which is the **environment** of the organisms which live within the soil. (*Marsh 1964*)

Soil complex

A mapping unit used in **detailed soil surveys** where two or more defined taxonomic units are so intimately intermixed geographically that it is undesirable or impractical (because of the scale being used) to separate them.

A more intimate mixing of smaller areas of individual taxonomic units than the **soil association**. (*Soil Conserv. Soc. Amer. 1970*)

Soil condition class

A reference to soil stability based principally on the amount of ground cover weighted by the degree of **accelerated erosion**. (*Amer. Soc. Range Manage. 1964*)

Soil conservation district (SCD, Soil and water conservation district, Natural resource district, Conservation district, Resource conservation district, RCD)

A subdivision of a state or territory organized pursuant to the state soil conservation district law, as amended, for the purpose, with the powers, and subject to the restrictions, determined by that law.

Under amendments to the districts' laws, the names of districts in some states have been changed to conservation districts, soil conservation districts, natural resource districts or, in California, resource conservation districts.

SCD's are locally created and operated. They are controlled by an elected and/or appointed governing body, generally made up of resident landowners. In most states, SCD's are under the general supervision of a state

conservation commission, committee, board, or agency.

Functions, operations, purposes, and powers of SCD's vary widely from state to state. (*U.S. Soil Conserv. Serv. 1970*)

Soil creep (Creep)

The slow, mass movement of soil material down relatively steep slopes, primarily under the influence of gravity but facilitated by saturation with water and by alternate freezing and thawing. (*Soil Conserv. Soc. Amer. 1970*)

Soil erosion. See **Erosion, soil.**

Soil family

1. Soil classes defined largely on the basis of physical and mineralogic properties of importance to plant growth. (*Soil Conserv. Soc. Amer. 1970*)

2. In soil classification one of the categories intermediate between the Great soil group and the soil series. (*Soil Sci. Soc. Amer. 1965*)

Soil fertility

The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil, are favorable. (*Soil Conserv. Soc. Amer. 1970*)

Soil great group (Great soil group)

Soil classes that are grouped upon the basis of having the same kind of horizons in the same sequence and similar moisture and temperature regimes. Exceptions to the soil horizon sequences are made for horizons near the surface that may get mixed or lost by erosion if plowed. (*Soil Conserv. Soc. Amer. 1970*)

Soil horizon (Soil zone)

1. A layer of soil, approximately parallel to the soil surface, with com-

paratively uniform characteristics produced by soil-forming processes.

One soil horizon is commonly differentiated from an adjacent one on the basis of characteristics that can be seen in the field. (*U.S. Soil Conserv. Serv. 1951*)

2. A term applied to a layer of soil which differs in composition or structure, or in both, from adjacent layers. The various horizons in a soil are generally described by a diagram representing a vertical section of the soil called a profile. The horizons in a soil profile are designated as follows: A-horizon, topsoil; B-horizon, mineral soil; and C-horizon, parent soil material, weathered or unweathered rock fragments and minerals.

Between any of the above horizons may be found a waterlogged or "gley" horizon, formed by the influence of ground water and marked by the presence of iron and other reduced compounds, alkaline salts, or aluminum oxides.

A layer under the C-horizon which is unlike the parent material may be indicated as a D-horizon on a soil profile. The A, B, and C-horizons are quite distinct in mature soils, developed under forest vegetation in temperate and humid climates. These are called "zonal soils". Soils in which the horizons are undistinguished are called "azonal". Where the horizons do not fall into the above pattern or some horizons are absent, the soils are called "intrazonal". (*Marsh 1964*)

Soil liquefaction (Thixotrophy)

The change of the strength of a water saturated, cohesionless soil to that of a liquid, usually from intense ground shaking. On liquefaction a soil loses all its bearing strength. (*Calif. Counc. on Intergov. Relat. 1973*)

Soil loss equation (Universal soil loss equation)

An equation used for the design of

water erosion control systems. $A = \text{RKLSPC}$ wherein A = average annual soil loss in tons per acre per year, R = rainfall factor, K = soil erodibility factor, L = length of slope, S = percent of slope, P = conservation practice factor, and C = cropping and management factor. (*Soil Conserv. Soc. Amer. 1970*)

The equation as originally developed predicted soil losses from agricultural lands induced by rainfall. A recent revision takes into account the effect of snowmelt in areas where the contribution from this cause is significant. (*J.H.H.*)

Soil-loss tolerance (Permissible soil loss, T factor)

The maximum average annual rate of soil erosion (whether from rainfall or wind) that will permit a high level of crop productivity to be sustained economically and indefinitely.

T factors of 1 through 5 are used, and these numbers represent the amount of soil loss in tons per acre per year that should be permitted on a given soil. The T factor is used in the soil-loss equations for rainfall and wind erosion. (*After Soil Conserv. Soc. Amer. 1970 and W.A.B.*)

Soil map

1. A map which shows the location and extent of the different soils in an area. Soil maps are prepared and published by various agencies of state and local governments, in cooperation with the U.S. Soil Conservation Service and/or Forest Service or by the Forest Service. (*After Marsh 1964*)

2. A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

The following kinds of soil maps are recognized in the United States: "detailed", "detailed reconnaissance", "reconnaissance", "generalized", and "schematic". (*Soil Conserv. Soc. Amer. 1970*)

Soil map, detailed

1. U.S. Soil Conservation Service usage. Referring to a soil map at a publication scale commonly of 2 inches = 1 mile on which soil types and soil phases are the main types of units delineated. The smallest unit size shown on such maps is about 1 1/3 acres. Survey traverses are usually made at 1/4 mile or more frequent intervals. The unit boundaries on detailed soil maps should have been seen throughout their course and their placement on the map should be accurate to at least 50 to 100 feet. The maximum amount of unlike soil inclusions in mapped units is 15 percent. (*After U.S. Soil Conserv. Serv. 1951 and Soil Sci. Soc. Amer. 1965*)

Soil map, detailed reconnaissance

A reconnaissance soil map on which some areas or features are shown in greater detail than usual, or than others. (*Soil Conserv. Soc. Amer. 1965*)

Soil map, general (Generalized soil map)

U.S. Soil Conservation Service usage. Referring to a soil map with a publication scale commonly of 1 inch = 1 mile on which soil associations and miscellaneous land types are the delineated units. The smallest unit size shown is about 3 1/2 acres. The maximum amount of unlike soil inclusions in such mapping units is 15 percent. (*After U.S. Soil Conserv. Serv. 1951 and 1971*)

Soil mapping unit

A kind of soil, a combination of kinds of soil, or miscellaneous land type or types, that can be shown at the scale of mapping for the defined purposes and objectives of the survey.

Soil mapping units are the basis for the delineations of a soil survey map. Mapping units normally contain inclusions of soils outside the limits of the taxonomic name, or names, used as

the name for the mapping unit. Mapping units are generally designed only to reflect significant differences in use and management. (*After Soil Conserv. Soc. Amer. 1970*)

Soil map, reconnaissance

U.S. Soil Conservation Service usage. Referring to a **soil map** of highly variable publication scale (1 inch = 1 mile to 1 inch = 8 miles) and quality. The most detailed units commonly shown are **miscellaneous land types** and **soil associations** or one or more phases of **soil families**. The smallest unit that can be shown on such a soil map at a scale of 1 inch = 1 mile is about 3½ acres and at 1 inch = 4 miles about 280 acres. Map unit boundaries are plotted where they cross field survey traverses. Traverses are at intervals varying from about ½ mile to several miles. Between these points of field observation most boundaries are sketched from the appearance of ground patterns on aerial photographs and the general appearance of the landscape. (*After U.S. Soil Conserv. Serv. 1951 and 1970 and Soil Sci. Soc. Amer. 1965*)

Soil order

The category at the highest level of generalization in the soil classification system. The properties selected to distinguish the orders are reflections of the degree of **soil horizon** development and the kinds of horizons present. (*Soil Conserv. Soc. Amer. 1970*)

Soil permeability. See **Permeability**.

Soil phase

A subdivision of a **soil taxonomic unit**, usually a **soil series** or other unit of classification based on characteristics that affect the use and management of the soil but which do not vary sufficiently to differentiate it as a separate soil series.

For example, a variation in a property or characteristic, such as degree of

slope, degree of erosion, content of stones, texture of the surface, etc.

Phases of soil series are the major components of the **soil mapping units** shown on **detailed soil maps** in the United States. (*Soil Conserv. Soc. Amer. 1970*)

Soil profile

1. A diagram of the vertical section of a soil showing the thickness and character of the various **soil horizons**. (*Marsh 1964*)

2. The succession of zones or "horizons" beginning at the surface that have been altered by normal soil-forming processes of which leaching and oxidation have been particularly important. (*Amer. Geol. Inst. 1962*)

Also see **Soil horizon**.

Soil region

An area with approximately uniform soils. Fifty soil regions are recognized in the United States, excluding Alaska and Hawaii. They are correlated with the climatic provinces and plant growth regions. A map of these regions is included in "Native Plants of the United States" by William R. Vansant, U.S. Department of Agriculture, miscellaneous publication no. 303. (*Marsh 1964*)

Soil resource inventory. In U.S. Forest Service usage this term is approximately equivalent to **soil survey**. See **Soil survey**.

Soil series

1. Soils which have similar **soil profile** characteristics and which are derived from similar **parent materials** are grouped together in a "soil series". A soil series is usually named for the locality where the typical soil was first recorded. (*Marsh 1964*)

2. A group of soils having **soil horizons** similar in differentiating characteristics and arrangement in the **soil profile** (except for texture of the surface portion); or, if genetic horizons

are thin or absent, a group of soils that, within defined depth limits, is uniform in all soil characteristics diagnostic for that series. (*Soil Conserv. Soc. Amer.* 1970)

Soil subgroup

Soil great groups are subdivided into subgroups that (1) show the central properties of the great group or (2) intergrade subgroups that show properties of more than one great group or (3) other subgroups for soils with atypical properties that are not characteristic of any great group. (*Soil Conserv. Soc. Amer.* 1970)

Soil survey

A general term for the systematic examination of soils in the field and in laboratories; their description and classification; the mapping of kinds of soil; the interpretation of soils according to their adaptability for various crops, grasses, and trees; their behavior under use or treatment for plant production or for other purposes; and their productivity under different management systems. (*Soil Conserv. Soc. Amer.* 1970)

The U.S. Forest Service now uses the term "soil resource inventory" rather than "soil survey". (*U.S. Forest Serv., FSM 2250.3, Aug. 1974*)

Soil taxon. See **Soil taxonomic unit.**

Soil taxonomic unit (Soil taxon)

A unit comprising all soils that fall within the defined limits of a class at any categoric level in a system of soil classification.

Commonly used as a member of the lowest class in the present classification scheme and in that use is equivalent to soil series. (*Soil Conserv. Soc. Amer.* 1970)

Soil texture

The relative proportions of the three individual particle size classes (i.e., sand, silt and clay) in a soil. (*After Soil Conserv. Soc. Amer.* 1970)

Soil type

1. A subdivision of a soil series based on surface soil texture. At the present time in the United States a soil type is considered as a kind of soil phase and is not part of the soil classification system presently being used. (*Soil Conserv. Soc. Amer.* 1970)

2. In Europe, a class roughly equivalent to a Great soil group. (*Soil Conserv. Soc. Amer.* 1970)

Soil variant

A kind of soil whose properties are believed to be sufficiently different from recognized soil series to justify a new series name but comprising such a limited geographic area that creation of a new series is not justified. (*Soil Conserv. Soc. Amer.* 1970)

Soil zone. See **Soil horizon.**

Solitude

1. An experience where man may commune with his surroundings in a natural setting generally undisturbed by the sound or sight of technology. (*U.S. Forest Serv. Region 9, 1975*)

2. The quality or state of being alone or remote from society. (*Webster 1963*)

Solum

1. The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B soil horizon. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plants and animal life characteristic of the soil are largely confined to the solum. (*Soil Conserv. Soc. Amer.* 1970)

2. In the agriculturally oriented usage of the term soil, the "solum" is the soil.

Special cutting

U.S. Forest Service usage. The term usually applies to logging activities in

special areas, such as recreation areas and administrative sites, where other uses or other values override timber production values. (*U.S. Forest Serv., FSM 2471.43, June 1973*)

Special exception (Exception)

An exception (or special exception) is the granting of a permit for a use which is a deviation from standard zoning practice, but it is anticipated within the **zoning ordinance** and provisions for "exceptions" are made within the text. A private school, for instance, would not ordinarily be permitted in an area zoned exclusively residential; yet, since this might be a perfectly desirable and acceptable place for a school, allowance for the exception, subject to close scrutiny by the zoners, will be pre-established on the books. (*Abrams 1971*)

Special interest area

U.S. Forest Service usage. Areas managed to make recreation opportunities available for the understanding of the earth and its geological, historical, archaeological, botanical, and memorial features. (*U.S. Forest Serv., 1971*)

For specific types of such areas see **Archaeological area**, **Botanical area**, **Geological area**, **Historical area**, **Paleontological area**, **Scenic area**, and **Zoological area**.

Special interest group

Any group (whether formally organized or not) with a specialized set of shared preferences about how resource use should be allocated. (*C.F.S.*)

Also see **Pressure group**.

Special management zone

U.S. Forest Service usage. Areas of unusual public interest or other significance. Examples are: wilderness, primitive areas, experimental forests, natural areas, scenic areas, and historical, geological, or archeological areas.

Such areas are classified or formally designated by the Congress, Secretary of Agriculture, Chief of the Forest Service, or Regional Foresters. (*U.S. Forest Serv., FSM 8223.3, Dec., 1974*)

Species biomass. See **Biomass**, definition 2.

Species diversity (Biologic diversity)

The number of different species occurring in some location or under some condition—such as water pollution.

Of the total number of species in a **biotic community** only a few are usually abundant while most are relatively uncommon. Because the large number of uncommon, relatively unimportant species largely determine the amount of "species diversity", this property is often expressed as a **species diversity index** which is calculated so as to better reflect the importance of those few species whose numbers, **biomass**, productivity, etc., so greatly dominate these attributes of the entire biological community. (*Odum 1971*)

Species diversity tends to be low in physically controlled **ecosystems** (i.e., subjected to strong physiochemical limiting factors) and high in biologically controlled ecosystems. Diversity tends to be high in older communities and low in newly established ones. (*Odum 1971*)

Diversity is directly correlated with **ecologic stability**, but it is not certain to what extent this relationship is a cause-and-effect one. (*Odum 1971*)

Species diversity index (Diversity index)

The ratio between the total number of species in a **biotic community** and some rating of the relative importance (numbers, **biomass**, productivity, etc.) of individual species.

"Diversity indices" provide one of the best ways to detect and evaluate pollution. (*Odum 1971*)

Species, edge

Species which occur primarily,

most abundantly or most of the time in the transition zones between two or more **biotic communities**—i.e., in the ecotone. (*Odum 1959*)

Species, endangered

1. An endangered species, or subspecies, of animal or plant is one whose prospects of survival and reproduction are in immediate jeopardy.

Its peril may result from one or many causes—loss of **habitat** or change in habitat, overexploitation, predation, competition, disease or even unknown reasons. An endangered species must have help, or extinction may follow. It must be designated in the Federal Register by the appropriate Secretary as an “endangered species.” (*After U.S. Forest Serv., FSM 2605, Sept., 1974*)

Species which are likely to become “endangered species” within the foreseeable future throughout all or a significant portion of their range are designated as **threatened species** in the Federal Register by appropriate Department Secretaries. (*Endangered Species Act of 1973*)

2. Any species which is in danger of extinction throughout all or a significant portion of its range—other than members of the class *Insecta* which have been determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man. (*Endangered Species Act of 1973*)

3. Animals are declared “endangered” by the California Fish and Game Commission because their continued existence is threatened by one or more conditions. If any of the following conditions are true, the species (or subspecies) under consideration is declared “endangered”: (A) the mortality rate consistently exceeds the birth rate; (B) it is incapable of adapting to environmental change; (C) its habitat is threatened by destruction or

serious disturbance; (D) its survival is threatened by the unwanted introduction of other species through predation, competition, or disease; or (E) environmental pollution threatens its survival.

Rare and endangered species are listed in the “Red Data Book” published by the International Union for Conservation of Nature and Natural Resources and in “Rare and Endangered Fish and Wildlife of the United States” compiled by the Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior. (*Calif. State Dep. of Fish and Game 1974*)

4. Those species in danger of extinction throughout all or a significant portion of their ranges.

Species or subspecies from very limited areas, e.g., the type localities only, or from restricted fragile habitats usually are considered “endangered”. (*Smithsonian Inst. 1975*)

Also see **Species, rare and Species, threatened**.

Species, endemic

A species whose natural occurrence is confined to a certain region and whose distribution is relatively limited. (*Hanson 1962*)

Species, exotic

1. U.S. Forest Service usage. Any species of **wildlife** not native to the continental United States. (*U.S. Forest Serv., FSM 2605, Sept., 1974*)

2. Any species that is not native in the area where it occurs. (*Hanson 1962*)

Species, feral

1. Non-native species, or their progeny, which were once domesticated but have since escaped from captivity and are now living as wild animals—such as wild horses, burros, hogs, cats and dogs. (*U.S. Forest Serv., FSM 2605, Sept., 1974*)

2. An organism (and its offspring) that has escaped from cultivation or

domestication and has reverted to a wild state. (*Hanson 1962*)

Feral is seldom used when referring to escaped plants. Escaped non-native plants are usually referred to as **exotics**, while escaped non-native animals are commonly referred to as either feral or exotic species. (*C.F.S.*)

Also see **Species, exotic**, **Species, naturalized**; contrast with **Species, resident**, **Native organism**, and **Endemic organism**.

Species, game

1. U.S. Forest Service usage. Any species of **wildlife** for which seasons and bag limits have been prescribed, and which are normally restricted to possession by sportspersons under state laws and regulations. (*U.S. Forest Serv., FSM 2605, Sept., 1974*)

2. Animals considered worthy of pursuit by sportspersons, especially wild animals hunted for sport or food. (*Webster 1963*)

Species, indigenous

1. U.S. Forest Service usage. Any species of **wildlife** native to a given land or water area by natural occurrence.

For planning purposes, indigenous species will include introduced or **exotic species** which have established a **niche** in the area's ecology and are compatible with national forest management objectives. Hungarian and chukar partridges are examples. (*U.S. Forest Serv., FSM 2605, Sept. 1974*)

2. An organism (plant or animal) that is native, not introduced, in an area. (*Hanson 1962*)

Species, introduced. See Species, exotic.

Species, keystone

A species which plays an important ecological role in determining the overall structure and dynamic relationships within a **biotic community**.

An evolutionary, component species of a biotic community whose

presence is essential to the integrity and stability of a particular **ecosystem**. (*Estes and Palmisano 1974*)

Keystone species may be unimportant as energy transformers in a biotic community (i.e., they may be neither very abundant nor consume large portions of the biotic productivity of a community). However slight variations in keystone species' abundance results in large changes in the abundance of other species and/or in biotic community relationships and structure. (*After Paine 1969*)

Species, local

A species with a relatively small range but which is sufficiently common not to be called rare. (*Little 1975*)

Species, native

Animals or plants which originated in the area in which they are found, (i.e., were not introduced and naturally occur in that area). (*Henderson, Henderson and Kenneth 1963*)

Also see **Endemic organism** and contrast with **Species, resident**; **Species, naturalized**; **Species, exotic**; and **Species, feral**.

Species, naturalized

A (non-native) species established as if it were a **native species**—for example the annual grasses of California's central valley and foothills. (*E.M.G.*)

Also see **Species, exotic**; **Species, feral**; contrast with **Endemic organism** and **Native organism**.

Species, peripheral (Boundary species)

1. U.S. Forest Service usage. A peripheral species, or subspecies, is one whose occurrence in the United States is at the edge of its natural range, and which is **rare** or **endangered** within the United States, although not in its range as a whole. Special attention is necessary to ensure retention in the nation's fauna. (*U.S. Forest Serv., FSM 2605, Sept. 1974*)

2. A species which reaches the limit of its natural range a short distance into a country (especially the U.S.) or some other boundary of significance to making planning area evaluations. (*After Little 1975*)

Species, rare

1. A rare species, or subspecies, is one that, although not presently threatened with extinction, is in such small numbers, throughout its range, that it may be endangered if its environment worsens. (*U.S. Forest Serv., FSM 2606.11, Aug. 1973*)

2. Species which occur in widely separated, small sub-populations, so that inbreeding between sub-populations is seriously reduced or is restricted to single populations. (*Drury 1974*)

3. A species which lacks the ability to displace other species in competition, to increase its population or to expand its range. (*Drury 1974*)

4. Classes of rare species according to geographical distribution:

Species occurring as a very few individuals or small groups at widely scattered localities over a large geographic area of what appears to be suitable habitat.

Species found in very small numbers widely dispersed in each community where they grow, but which occur in many suitable areas over their geographic range.

Species with a range restricted to so few localities that they are considered rare even though they occur in large numbers at each locality. (*Drury 1974*)

5. Animals are declared "rare" by the California Fish and Game Commission because their continued existence is threatened by one or more conditions. If any of the following conditions are true, the species (or subspecies) under consideration is declared rare: (A) it is confined to a relatively small and specialized habitat, and it is

incapable of adapting to different environmental conditions; (B) although found in other parts of the world, it is nowhere abundant; (C) it is so limited that any appreciable reduction in range, numbers, or habitat would cause it to become **endangered**; or (D) if current management and protection programs were diminished in any degree, it would become endangered.

Rare and endangered species are listed in the "Red Data Book" published by the International Union for Conservation of Nature and Natural Resources and in "Rare and Endangered Fish and Wildlife of the United States" compiled by the Bureau of the Sport Fisheries and Wildlife, U.S. Department of the Interior. (*Calif. State Dep. of Fish and Game 1974*)

Also see **Species, threatened** and **Species, endangered**.

Species, recently extinct or possibly extinct

Those species no longer known to exist after repeated search of the type localities and other known or likely places.

Some species may be extinct in the wild but are being preserved by cultivation in gardens or as domesticated animals. (*After Smithsonian 1975*)

Species, resident

Species common to an area without distinction as to being native (i.e., **native organism** or **endemic organism**) or introduced (i.e., **exotic species**, **naturalized species** or **feral species**). (*Amer. Soc. Range Manage. 1964*)

Species, status undetermined

U.S. Forest Service usage. A species, or subspecies, that has been suggested as possibly being **endangered** but about which there is not enough information to determine its true status. (*U.S. Forest Serv., FSM 2605, Sept. 1974*)

species, threatened

1. Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and which has been designated in the Federal Register by the Secretary of Interior as a threatened species. (*Endangered Species Act of 1973*)

This includes species categorized as rare, very rare, or depleted. (*Smithsonian Inst. 1975*)

Also see **Species, endangered** and **Species, rare**.

species, unique

U.S. Forest Service usage. Species which are not **endangered**, but have considerable scientific, local, or national interest. (*U.S. Forest Serv., FSM 2605, Sept. 1974*)

splash erosion. See Erosion, splash.

spoil bank (Spoil heap, Spoil pile)

The place on the surface where any dirt or rock which has been removed from its original location by mining operations accumulates or is piled up—especially the waste deposits from **surface mining**. (*After Thrush 1968*)

spoils. See Mining spoils.

spot grazing

Repeated grazing of small areas while adjacent areas are lightly grazed or unused. (*Amer. Soc. Range Manage. 1964*)

spot zoning. See Zoning, spot.

stability. For biologic and ecologic usage of this term, see **Ecologic stability**.

stand (Concrete community, Individual association)

1. U.S. Forest Service usage. A growth of trees on a minimum of 1 acre of forest land that is at least 10 percent stocked by forest trees of any size. (*U.S. Forest Serv. 1972B*)

2. A stand is an aggregation of trees or other growth occupying a specific area and sufficiently uniform in

composition (species), age arrangement, and condition as to be distinguishable from the forest or other growth on adjoining areas. (*U.S. Forest Serv., FSM 2471.4, May, 1972*)

3. A stand need not be limited to trees. Any group of plants satisfying the definition of a **plant community** may be so termed—a mat of lichens on a rock, covering only a few square inches, an algal mat on a pond, or a forest of fairly homogeneous composition extending over a thousand acres or more. (*Oosting 1956*)

Standard

1. A statement which describes a condition when a job is done properly. Standards show how well something should be done, rather than what should be done. (*U.S. Forest Serv. 1971*)

2. Regulatory and pollution standard usage. A plan that is established by governmental authority as a program for prevention and abatement of resource degradation.

The terms “standards” and **objectives** can be used interchangeably. (*After U.S. Fed. Water Pollut. Control Adm. 1968*)

Any definite rule, principle or measure established by authority. (*After Mc Kee and Wolf 1963*)

An authoritative origin does not necessarily mean that a “standard” is fair, equitable, or based on sound scientific knowledge, (e.g., of the functional cause-effect relationship between specific pollutant concentrations and the resulting levels of damage) for it may have been established somewhat arbitrarily on the basis of inadequate technical data tempered by a cautious factor of safety. (*After Mc Kee and Wolf 1963*)

Also see regulatory and pollution criteria under **Criteria**.

Standard metropolitan statistical area (SMSA)

U.S. Bureau of the Census usage. As defined by the Bureau of the Census in 1960, a county or group of contiguous counties that contains at least one city of 50,000 inhabitants or more (or "twin cities" with a combined population of at least 50,000); also, contiguous counties essentially metropolitan in character and socially and economically integrated with the central city. In New England, the SMSA is defined on a town rather than county basis. (Abrams 1971)

The SMSA is of importance to planners since much of the information collected in the census and useful for research or analysis is organized on a SMSA basis. (E.C.T.)

For the SMSA's relationship to an "urbanized area" see **Urbanized area**.

For SMSA's relationship to "state economic area", see **State economic area**, definition 2.

Standard of living

Standards of living constitute an organic whole, touching every phase of the life of the individual, the family, or the group. They concern the kind and quantity of food consumed, the sort of house lived in, clothing worn, etc., as well as the various cultural elements of existence, such as education, recreation, participation in church and civic organizations, and numerous other activities. (Soil Conserv. Soc. Amer. 1970)

Also see **Quality of life**.

Stand cutting

U.S. Forest Service usage. A **clear-cutting system** variation in which the logging operation removes all merchantable timber from areas that are large enough to be practical for future management as uniform **even-aged** stands.

The minimum size will be 100 acres and the maximum size, 500 acres. (After U.S. Forest Serv., FSM 2471 R-3)

Also see **Group cutting**, definition

2, for a comparison with similar logging approaches.

Standing crop (Standing biomass, Standing crop biomass, Standing stock)

1. The total amount of the **biomass** of organisms of one or more species within an area. (Hanson 1962)

2. The total number or the total weight of one or more species of animals in an area at a given time. (Ford-Robertson 1971)

3. Note that the emphasis in the term **biomass** is on weight per unit area; in "standing crop" it is on the summation of all those weights per unit area over some spatial extent of concern.

Stand tending. See **Intermediate cutting**.

State economic area

1. U.S. Bureau of the Census usage. Single counties or groups of counties which have similar economic and social characteristics. The boundaries of these areas have been drawn in such a way that each state is subdivided into relatively few parts, with each part having certain significant characteristics which distinguish it from adjoining areas.

In the 1970 U.S. Census there were 510 "state economic areas." (U.S. Bur. Census 1971)

2. Relation to **standard metropolitan statistical areas**. The combination of counties into state economic areas has been made for the entire country, and in this process the larger **standard metropolitan statistical areas** (those in 1960 with a central city of 50,000 or more and a total population of 100,000 or more) were recognized as "metropolitan state economic areas". When a standard metropolitan statistical area was located in two or more states or economic subregions, each state part and each part in an economic subregion became a separate metropolitan state economic area. In New

England this correspondence of "metropolitan state economic areas" and "standard metropolitan statistical areas" did not exist because state economic areas are composed of whole counties, whereas standard metropolitan statistical areas are built up from towns. Here a county with more than half its population in one or more "standard metropolitan statistical areas" was classified as a metropolitan "state economic area" if the county or a combination of counties containing the standard metropolitan statistical area or areas had 100,000 inhabitants or more. (*U.S. Bur. Census 1971*)

tation point

1. The location from which something is viewed. (*After Litton 1968*)

2. The location of the viewer as that person looks upon a visual objective, particularly with regard to being below, at the same level as, or above the visual objective. (*Litton 1968*)

tatus, social. See **Social status.**

tatus undetermined species. See **Species, status undetermined.**

teno- organism

A prefix denoting an organism which can only tolerate a narrow range of changes of one or more of its environmental conditions. For example, stenothermal refers to organisms which can not tolerate much change in temperature. (*Hanson 1962*)

Also see **Eury- organism** for organisms that can tolerate large changes.

tochastic model. See **Model, probabilistic.**

tochastic process

Any process whose development in time is governed by chance or probabilistic considerations. (*U.S. Forest Serv. 1972B*)

tocking level

In a forest, a more or less subjective indication of the number of existing

trees as compared to the desirable number for best results—e.g., maximum productivity of wood. (*After Ford-Robertson 1971*)

Stocking plan

The number and kind of livestock assigned to one or more given **management areas** or **management units** for a specified period. (*Amer. Soc. Range Manage. 1964*)

Stocking, proper

Range management usage. Placing a number of animals on a given area that will result in proper use at the end of the planned grazing period.

Continued proper stocking will lead to proper grazing. (*Amer. Soc. Range Manage. 1964*)

Stocking rate (Grazing rate)

Range management usage. The actual number of animals, expressed in either **animal units** or **animal unit months**, on a specific area at a specific time. (*Amer. Soc. Range Manage. 1964*)

Stock resource. See **Nonrenewable resource.**

Storie index

A numerical expression of the degree to which a particular soil presents conditions favorable for plant growth and crop production under favorable climate and adequate moisture conditions.

Four general factors are considered: (1) the character of the **soil profile**; (2) **soil texture**; (3) slope of the land and; (4) other modifying factors such as drainage, salinity, alkalinity, soil acidity, erosion conditions, fertility level and microrelief. Each of these four factors is evaluated on the basis of 100 percent for the most favorable or ideal conditions, with limiting maximum and minimum ratings ascribed to conditions that are less favorable for plant growth. (*Storie 1964*)

Strategic planning

The study of **objectives** and analysis of alternative ways to achieve objectives in terms of their relative costs and accomplishments. (*U.S. Forest Serv. 1972B*)

Strategy

1. A consideration of alternative means to reach an objective. (*U.S. Forest Serv. 1971*)

2. A carefully thought out plan or method for achieving a goal or objective. (*After Webster 1963*)

Stratification (Land stratification)

1. This term commonly infers both mapping and **classification**.

For example, the "soils are stratified"; meaning they have been mapped, examined, grouped, and delineated to a given classification key or base. (*U.S. Forest Serv. 1972B*)

2. A land use planning concept which was probably borrowed from the statistical technique of "stratified sampling" which subdivides a study area into units which are, more or less, internally homogeneous with respect to the (those) character(s) of interest. Subsequently, sampling data is taken to characterize each unit. This strategy provides maximum information for an economy of sampling effort.

Land use planning has adopted the concept in the sense that a planning unit can theoretically be classified into **homogeneous response units** about which useful generalizations can be made without having to make **site specific** studies. (*C.F.S.*)

Stream load

The quantity of solid and dissolved material carried by a stream. (*Soil Conserv. Soc. Amer. 1970*)

Strip cutting

U.S. Forest Service usage. A **clear cutting system** variation in which the logging operation removes all merchantable timber from areas that run

through a stand and are usually of width equal to one or two times the general stand height. (*After U.S. Forest Serv., FSM 2471 R-3*)

Also see **group cutting**, definition 2 for a comparison with similar logging practices.

Strip mining. See **Mining, strip.**

Strip pit

1. A coal or other mine worked by stripping away the surface soil and rock above a mineral deposit. (*Thrus. 1968*)

2. An **open-pit mine**. (*Thrus. 1968*)

3. That part of a strip mining operation from which minerals are being or have been removed from their natural state. (*Grim and Hill 1974*)

Stumpage value

The value of timber as it stands uncut in terms of an amount per cubic unit. (*Ford-Robertson 1971*)

Subclimax

A stage in **succession** short of the **climax community** in which further development is inhibited by the influence of some factors other than climatic factors. (*After Hanson 1962*)

Subculture (Group culture)

Refers to the more or less different **folkways** and **mores** developed by each group within a society. Groups with common play, age, vocational, sexual, habitational, or other interests evolve behavior patterns that differ from those of other groups and from society's conventions. (*O'Connell 1974*)

Subdivision (Land subdivision)

1. The process of dividing a given area of undeveloped land into individual home sites and/or blocks of lots with streets or roads and open spaces. (*After Abrams 1971*)

2. Also an area which has been subdivided. (*Abrams 1971*)

3. A tract of land surveyed and di-

vided into lots for purposes of sale. (Webster 1963)

bmarginal land

Land which is economically incapable of sustaining indefinitely a certain use or ownership status. (*Amer. Soc. Range Manage.* 1964)

boptimization

1. The selection of the best alternative course of action which pertains to a subproblem, that is, to only part of the overall problem or objective.

Suboptimization is usually necessary because alternatives at all the various levels of decision making cannot, as a practical matter, be analyzed simultaneously before decisions are made at any level. (*U.S. Gen. Account. Off.* 1969)

2. Any intermediate stage in a long-run goal attainment program. (*U.S. Gen. Account. Off.* 1969)

ubsidence

A downward movement of the ground surface caused by solution and collapse of underlying soluble deposits, rearrangement of particles upon removal of underground mineral deposits, or reduction of fluid pressures within an aquifer or petroleum reservoir. (*Soil Conserv. Soc. Amer.* 1970)

ubsoil

The B soil horizon of soils with distinct soil profiles. In soils with weak profile development, the subsoil can be defined as the soil below the soil in which roots normally grow (i.e., below the plowed soil or its equivalent of surface soil).

Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as the "subsoil". (*Soil Conserv. Soc. Amer.* 1970)

ubsurface rights. See Mineral rights.

Succession (Ecologic succession, Ecosystem development)

1. It is an orderly process of **biotic community** development that involves changes in species, structure and community processes with time; it is reasonably directional and, therefore, predictable.

It results from modification of the physical environment by the community: that is, "succession" is community-controlled even though the physical environment determines the pattern, the rate of change, and often sets limits as to how far development can go.

It culminates in a stabilized ecosystem in which maximum **biomass** and symbiotic function between organisms are maintained per unit of available energy flow.

The whole sequence of communities that replaces one another in a given area is called the **sere**; the relatively transitory communities are variously called "seral stages" or "developmental stages" or "pioneer stages", while the terminal stabilized system is known as the **climax**.

Species replacement in the sere occurs because populations tend to modify the physical environment, making conditions favorable for other populations until an equilibrium between biotic and abiotic is achieved. (*Odum* 1971)

A "sere" whose first stage is open water is termed a "hydrosere", one whose first stage is dry ground, a "xerosere". Succession is "primary" on sites that have not previously borne vegetation, "secondary" after the whole or part of the original vegetation has been supplanted, "allogenic" when the causes of succession are external to and independent of the community (e.g., accretion of soil by wind or water, or a change of climate) and "autogenic" when the developing vegetation is itself the cause. (*Ford-*

Robertson 1971)

2. The process of replacement of one plant community by another until the **climax** community is reached. (Durrenberger 1973)

Succession, primary (Prisere)

1. **Successions** beginning from newly formed soils or upon surfaces exposed for the first time (as by landslides) which have as a consequence never borne vegetation before. (Carpenter 1938, citing Clements 1905)

2. Any succession beginning on a bare area, such as a lava flow, not previously occupied by plants or animals. (Hanson 1962)

Also see **Succession, secondary**.

Succession, secondary

1. Any **succession** caused by man or human agency. (Carpenter 1938)

Successions on denuded soils. (Carpenter 1938, citing Clements 1905)

2. The kind of succession which takes place following the destruction of part or all of the vegetation in an area, usually caused directly or indirectly by man. (Hanson 1962)

Suitability

1. In land use planning literature the widely used terms "suitability" and "capability" (whether alone or accompanied by various modifiers) are often used interchangeably to refer to ratings based on two basically different evaluation procedures. One basic type of evaluation procedure is the rating of use or productivity potentials based on the present state of the resource. This type of rating therefore is an evaluation based on the resource's inherent, natural or intrinsic ability to provide for use and includes that existing ability which is the result of past alterations or current management practices. A second basic type of evaluation procedure rates the potential ability of a resource to produce goods or services on the basis of the maximum possible outputs for a given type

and level of future, alternative site or resource management inputs.

G. Angus Hills was probably the first prominent wildland planner to recognize the importance of retaining the distinction between these and other types of evaluations in a process for land use planning. Hills used the terms **use capability** to refer to evaluations based on a resource's inherent or present condition abilities, **use suitability** for evaluations based on potential management inputs, and **use feasibility** to refer to usability potential ratings based on an evaluation of off-site factors—such as **accessibility**, present and **forecasted** socioeconomic conditions, technological developments, etc. (Belknap and Furtado 1967; Hills, Love and Lacate 1970)

Perhaps even earlier than Hills, the U.S. Soil Conservation Service began widespread use of its **Land Capability Classification System** (Wohletz and Dolder 1952) which also uses "capability" evaluation in the sense of an inherent ability rating.

To avoid confusion in the future we recommend that the Hills and Soil Conservation Service usages be recognized as having established the precedent for the proper usage of these terms. Thus "capability" should be used when referring to evaluations for usability based on the present state of the resource and "suitability" should only be used for evaluations based on assumptions about potential usability or productivity if specified management alterations were to be made—such as drainage improvements, added irrigation and/or fertilization, etc.

Better yet, both terms should be accompanied by modifiers which make it absolutely clear just what type of an evaluation procedure is implied by the rating given. Thus the word capability should always be presented as "inherent capability", "intrinsic capability", or "natural capability". Similarly

"suitability" could be referred to as "managed suitability". (*C.F.S.*)

2. Range management usage. The adaptability of an area to grazing by livestock or game or the adaptability of a particular plant or animal species to a given area. (*Amer. Soc. Range Manage. 1964*)

Suitability, inherent. See **Capability**.

Suitability, intrinsic

Ian Mc Harg's usage. Locations within a planning area displaying the maximum coincidence of favorable natural environmental factors relevant to the location of a prospective land use and the fewest constraints on that use. (*Wallace, Mc Harg, Roberts and Todd 1972*)

Also see **Capability**.

Suitability, managed. See **Suitability**.

Suitable range. See **Range, suitable**.

Supplement

1. Something that makes an addition; something that completes, adds a finishing touch, or brings closer to completion or a desired state. (*Webster 1963*)

2. The relationship between complements and supplements to plans is that complements can be viewed as being mutual supplements while supplements do not gain anything unto themselves by their addition to a plan. (*C.F.S.*)

Also see **Complement**.

Supply. See **Supply schedule**.

Supply schedule (Supply)

The amount of a good or service that will be offered for sale over a given range of prices at a particular point in time. (*U.S. Forest Serv. 1972B*)

The U.S. General Accounting Office titles of output that will be offered for sale or use during a planning period at specified output prices or price assumptions. (*U.S. Forest Serv. 1972B*)

Surface erosion. See **Erosion, surface**.

Surface mining. See **Mining, surface**.

Surface restoration. See **Reclamation**.

Surface rights

1. The ownership of the surface of the land only, where the **mineral rights** have been separately reserved. (*Thrush 1968*)

2. Those ownership rights reserved to the owner of the land beneath or from which ore is being mined. (*Thrush 1968*)

3. The right of a mineral owner to use so much of the surface of the land as may be reasonably necessary for the conduct of mining operations. (*Thrush 1968*)

Surface soil (Topsoil)

The uppermost part of the soil ordinarily moved in tillage (or its equivalent in uncultivated soils) ranging in depth from 5 to 8 inches.

Frequently designated as the "plow layer," the A_p layer, or the A_p **soil horizon**. (*Soil Conserv. Soc. Amer. 1970*)

Surface storage

The sum of **detention storage** and **channel storage**, representing, at any given moment, the total water enroute to an outlet from an area or watershed. (*Soil Conserv. Soc. Amer. 1970*)

Surface water

Water which remains on top of the land, such as a river or lake. (*E.C.T.*)

Suspended load

1. The smaller **sediment** particles that are lifted far from the bottom for long periods by running water and are distributed through the whole body of the current. (*Amer. Geol. Inst. 1962*)

2. The quantity of **suspended sediment** actually transported by a current. (*Amer. Geol. Inst. 1962*)

Suspended sediment

Sediment which remains suspended

in the water for a considerable period of time without coming in contact with the bottom. (*Amer. Geol. Inst. 1962*)

Suspended solids

The small, solid particles in water or sewage that cause a cloudy condition in water. (*Sesco, et al. 1973*)

Sustained production. See **Sustained yield.**

Sustained yield (Sustained production)

1. The achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources . . . without impairment of the productivity of the land. (*After Multiple Use-Sustained Yield Act*)

2. The yield that a forest can produce continuously at a given intensity of management.

Sustained-yield management, therefore, implies continuous production so planned as to achieve at the earliest practical time a balance between increment and cutting. (*Ford-Robertson 1971*)

3. The yield that a renewable resource can produce continuously at a given intensity of management. (*After Ford-Robertson 1971*)

Sweet spoils. For mining usage see **Mining**

debris, sweet.

Synergism

The combined action of two or more agents that is greater than the sum of the actions of each of the agents used alone. (*Webster 1963*)

See **Antagonism** for combined actions which are less than a simple summation of individual actions.

System

1. An organized collection of parts united by regulated interaction. (*U.S. Forest Serv. 1972B*)

2. A group of components which are interrelated to each other in such a way that changes in one component can affect some, or all of the other components. (*Williams 1971*)

System planning. See **Functional planning.**

Systems analysis

An integrated, step by step approach for helping a decision maker choose a course of action by investigating his full problem, searching out objectives and alternatives, and comparing them in the light of their consequences, using an appropriate framework (in so far as possible analytic and quantitative) to bring expert judgement and intuition to bear on the problem. (*Quade and Boucher 1968*)

T

Tailings. See **Mine tailings.**

Taking

1. A violation of the U.S. Constitutional provision "... nor shall private property be taken for public use without just compensation . . ." by a system of land use regulation. (*After Boselman, et al. 1973*)

Although the Fifth Amendment's prohibition of "takings" of property without "just compensation" applied to the states by virtue of the Fourteenth Amendment (Chicago, B. and

O. Rr. vs. Chicago, 166 U.S. 226 (1897)), it has long been established that state regulation based on the police power may substantially diminish the economic value of private property without giving rise to an obligation to compensate the owner. See e.g., *Mugler vs. Kansas*, 123 U.S. 623 (1887); *Euclid vs. Ambler Realty Co.*, 272 U.S. 365 (1926). There is a very hazy boundary between "taking" (compensation required) and "police power" regulation (compensation not re-

quired). The Supreme Court itself has acknowledged that "there is no set formula to determine where regulation ends and taking begins" (Goldblatt vs. Hempstead, 369 U.S. 590, 594 (1962)). In the language of the decided cases, the phrase "police power" normally connotes that the action in question is being taken without compensation to the property owner. By contrast, where compensation for a "taking" is contemplated, the cases speak of "eminent domain" or "expropriation" powers.

Most of the Supreme Court cases in this area have involved zoning laws or other governmental action largely unrelated to environmental concerns. See, e.g., *United States vs. Causby*, 328 U.S. 256 (1946). However, in recent years, several state court decisions have invalidated, under the Federal or state constitutions, state or local police power (no compensation) initiatives designed primarily to preserve the natural environment. See, e.g., *Bartlett vs. Zoning Commission*, 232 A. 2D 907 (Conn. 1971); *Maine vs. Johnson*, 265 A. 2D 711 (ME 1970); *Dooley vs. Town Plan and Zoning Commission*, 197 A. 2D 770 (Conn. 1964). (*From U.S. Dep. Justice comments in U.S. Congr., Senate Com. Inter. Insular Aff. 1973*)

2. An issue in planning centering around the right of the government to control private use of private land, in effect taking away property rights for the common good. It involves purchasing lands through eminent domain for special purposes, compensation for decreased property values due to regulation, and the rights of private ownership versus public needs. (*E.C.T.*)

Also see **Eminent domain**, **Just compensation**, **Police power**, and **Development rights**, **acquisition of**.

Target

A clear and concise statement used to express planned results to be

reached within a stated time period. Results must be measured in terms of some specific indicators, may include **standards**, and must be relatable to some **criteria** for how well they were achieved. Often one or more separate targets are used to make an **objective** explicit and to achieve its desired state or purpose. (*U.S.D.A. Off. Manage. and Finance 1974*)

Taxonomy

1. The science of classification of organisms; the arrangement of organisms into systematic groups such as species, genus, family, and order. (*D.E.H. and B.W.*)

2. "Taxonomy" is a term closely related to **classification** but it embodies a broader concept.

Taxonomy is the science of how to classify and identify.

It is the theoretical study of classification including its bases, principles, procedures, and rules.

Taxonomy includes classification as well as identification. (*Sokal 1974*)

Technological assessment (Technological forecasting)

The attempt to estimate or predict the completely new technological developments which will occur in the future; and, to evaluate the extent to which such likely, future new abilities will be able to solve (or at least acceptably minimize) current land use problems, or problems which are expected to be associated with particular land uses in future times. (*C.F.S.*)

Technological change

1. The increase of our ability to solve problems or increase efficiency by technical means with time. (*C.F.S.*)

2. The increase with the passage of time of the availability of alternative or completely new technical methods for solving problems associated with land uses because of the inevitable evolution and development of new ideas.

Thus, for those land use problems

which are potentially resolvable by technical means, what may be essentially impossible to do now because of the lack of available technology most likely will become possible in some future time period. (*C.F.S.*)

Technological forecasting. See **Technological assessment.**

Technological solution

1. The application of the devices or techniques developed by science for practical purposes.

A technical method for achieving a practical purpose. (*After Webster 1963*)

2. In land use planning this concept is especially used in the context of the emergence of completely new technical methods for solving current or potential problems for which no "technological solutions" presently exist. (*C.F.S.*)

Also see the related terms **Technological assessment**, **Technological change**, **Engineering solution**.

The distinction between "technical solutions" and "engineering solutions" is that the first refers just to the development of new technical means while the last applies to the application of any technical means (new or old) to solving potential problems. (*C.F.S.*)

Temporary license. For range management usage see **Temporary permit**.

Temporary pasture. See **Pasture**, **supplemental**.

Temporary permit (Temporary license)

Range management usage. A document authorizing grazing a certain number of livestock on public lands during an emergency or for a certain period, terminable at the end of such period and with no guarantee of renewal in whole or in part. (*Amer. Soc. Range Manage. 1964*)

Also see **Term permit**.

Terminal facilities

Terminal facilities are fixed ad-

juncts of the **transportation network** and serve as a transfer interface between the transportation network and resources served or between different transportation modes. Typical terminal facilities are vehicle parking areas, boat ramps and docks, trail heads, log landings and dumps, and air fields and heliports. (*U.S. Forest Serv., FSM 7705.24*)

Term license. For range management usage see **Term permit**.

Term permit (Term license)

Range management usage. A document which authorizes grazing on public lands for a stated number of years as contrasted with an annual or **temporary permit**. (*Amer. Soc. Range Manage. 1964*)

Also see **Temporary permit**.

Terrain (Terrane)

1. The physical features of a tract of land. (*Webster 1963*)

2. An area of ground considered as to its extent and natural features in relation to its use for a particular operation. (*Amer. Geol. Inst. 1962*)

A tract of country considered with regard to its natural features, configuration, etc.; in military use especially as affecting its tactical advantages, fitness for maneuvering, etc.; also an extent of ground, region, district, territory. (*Stamp 1961*)

Terrain analysis

The process of interpreting a geographical area to determine the effect of the natural and man-made features on a particular activity. This interpretation includes the influence of weather and climate on those features. (*Amer. Geol. Inst. 1962*)

Terrain evaluation. See **Land evaluation**.

Terrain factor

1. Terrain factors consist of land forms, drainage features, ground, vegetation, etc. and cultural features or

man-made changes in the earth's surface. (*Amer. Geol. Inst. 1962*)

2. A specific attribute of the terrain that can be described in quantitative terms. (*U.S. Dep. Defense 1968*)

Terrain studies

Regional studies usually with an emphasis on relief and essential physical features—soil, vegetation, and drainage. (*Stamp 1961*)

errane. See Terrain.

Territoriality

The behavior by which an organism claims an area and defends it against members of its own species. (*Worthington 1974*)

Tertiary facility

Transportation planning usage. Tertiary facilities are usually intended to provide access for a specific resource utilization activity, such as a timber sale or recreation site, although other minor uses may be served. Emphasis is given to resource service rather than travel efficiency. Tertiary facilities may often be developed and operated for short term or intermittent service. (*U.S. Forest Serv., FSM 7705.43 Aug., 1975*)

Also see Primary facility and Secondary facility.

Tertiary sewage treatment. See Tertiary wastewater treatment.

Tertiary treatment. See Tertiary wastewater treatment.

Tertiary wastewater treatment (Tertiary treatment, Tertiary sewage treatment)

Wastewater treatment processes, beyond "primary" and secondary wastewater treatment, which remove or reduce the amount of nitrate and phosphate nutrients still present in their effluents. Tertiary treatment may consist of extensions or modifications of secondary treatment processes, additional forms of chemical treatment, electrochemical processing, carbon fil-

tration, and other more complex procedures. (*After Wash. State Univ., Coop. Ext. Serv. 1972*)

Tertiary treatment removes up to 99 percent of the suspended solids and biological oxygen demand, 95 percent of the phosphate and 75 percent of the nitrate from wastewater. (*Martin and Weinberger 1966*)

T factor. For soil erosion related usages see Soil loss tolerance.

Thermal enrichment. See Thermal pollution.

Thermal pollution (Thermal enrichment, Calefaction)

Altering the amount of energy available in the environment by the addition of heat or cold. Most frequently this occurs in the form of the heat added by returning water which has been used for cooling purposes to a river, lake, estuary, bay or the ocean. However "thermal pollution" may also occur with the release of large volumes of the cold, deep water in reservoirs into warmer bodies of water. (*E.C.T.*)

Thinning

Cutting made in an immature crop or stand in order primarily to accelerate the diameter increment (annual growth) of the residual trees but also, by suitable selection, to improve the average form of the trees that remain, without (at least according to classical concepts) permanently breaking the canopy. (*Ford-Robertson 1971*)

Thixotrophy. See Soil liquefaction.

Threatened species. See Species, threatened.

Threshold level

The minimum concentration or amount of a given substance or condition necessary to produce a measurable physiological or psychological effect. (*Sesco, et al. 1973*)

Timber management compartment

U.S. Forest Service usage. A compartment is defined as an organization unit or small subdivision of forest area for purposes of orientation, administration, and silvicultural operations, and defined by permanent boundaries (either of natural features or artificially marked) which are not necessarily coincident with stand boundaries. (*U.S. Forest Serv., FSM 2412.3*)

Timber planning

Functional planning for the growth and harvesting of commercial trees. (*E.C.T.*)

Also see **Functional planning**.

Timber Resource System

U.S. Forest Service usage. The role of the Timber Resource System is to grow and make available wood for the nation on a continuing basis. Thus, the system includes those activities necessary to (1) protect, improve, grow, and harvest timber from forest land and (2) protect, process, and utilize wood and wood-related products. In addition to wood, the system produces other goods and services, either by design or incidentally.

One of the six "systems" established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act of 1974**. It has grouped its various programs into these six "systems," each of which incorporates all the activities concerned with developing and managing a specific resource. (*After U.S. Forest Serv. 1974A*)

The six "systems" are: **Land and Water**, "Timber Resource", **Outdoor Recreation and Wilderness**, **Rangeland Grazing, Wildlife and Fish Habitat**, and **Human and Community Development**.

Timber type. See **Cover type**, definition 1.

Time zoning. See **Zoning**, time.

TL_m. See **Median tolerance limit**.

Tolerance

1. The resistance of an organism to the excess or the deficiency of an element or a condition in its **environment**—e.g., elm trees are "resistant" to periodic flooding. (*Dansereau 1957*)

2. The capacity of an organism or biological process to subsist under a given set of environmental conditions, such as high levels of pollution. (*Sesco, et al. 1973*)

For **soil erosion** related usages see **Soil loss tolerance**.

Topography

The configuration of a surface including its **relief**, elevation and the position of its natural and man-made features.

The physical or natural features of an object or entity and their structural relationships. (*Webster 1963*)

Topsoil

1. Earthy material used as top-dressing for house lots, grounds for large buildings, gardens, road cuts, or similar areas. It has favorable characteristics for production of desired kinds of vegetation or can be made favorable. (*Soil Conserv. Soc. Amer. 1970*)

2. The surface plow layer of a soil. Synonymous with **surface soil**. (*Soil Conserv. Soc. Amer. 1970*)

3. The original or present dark-colored upper soil that ranges from a mere fraction of an inch to two or three feet thick on different kinds of soil. (*Soil Conserv. Soc. Amer. 1970*)

4. The original or present "A" **soil horizon** varying widely among different kinds of soil.

Applied to soils in the field, the term has no precise meaning unless defined as to depth or productivity in

relation to a specific kind of soil. (*Soil Conserv. Soc. Amer.* 1970)

Tractor logging. See **Logging, tractor.**

Trade-offs

The combination of **benefits** and **costs** which are gained and lost in switching between alternative courses of action. "Trade-offs" include only those portions of benefits and costs which are not common to all alternative courses of action under consideration. (*E.C.T.*)

Traffic classification. See **Traffic composition.**

Traffic composition (Traffic classification)

The **classification** and grouping of the various sizes and weights of vehicles making up the traffic of a road such as passenger cars and trucks. This is frequently called traffic classification. (*U.S. Forest Serv., FSH 7709.11, May 1969*)

Traffic volume

The number of vehicles traveling in both directions past a given point during a specified period of time. This is usually expressed as seasonal **average daily traffic** for roads that are open only part of the year, or annual **average daily traffic** for roads (highways) open year round. (*U.S. Forest Serv., FSH 7709.11, May 1969*)

Trampling

Treading under foot; the damage to plants or soil brought about by movements or congestion of livestock and/or people. (*After Amer. Soc. Range Manage.* 1964)

Transitory range. See **Range, transitory.**

Transportation network

U.S. Forest Service usage. The transportation network includes all existing and planned roads, trails, bridges, airfields, and other transport facilities wholly or partly within or ad-

jacent to and serving the planning area. (*After U.S. Forest Serv., FSM 7705.21, Aug. 1975*)

Transportation planning

The process by which new transportation facilities (and improvements to the old facilities) are systematically designed, their adequacy tested, and their future construction **programmed**. Comprehensive transportation planning considers all modes (mass transit, automobile, air, rail, etc.) of transportation and regards the total as a single system. Transportation planning is a type of **functional planning**. (*After Abrams 1971*)

Also see **Functional planning.**

Transportation services land

U.S. Soil Conservation Service usage. Land used primarily for highways, roads, beltways, railroads, utility rights-of-way, airports, and other transportation facilities, together with necessary adjacent facilities such as approaches, underground and surface utilities, and other servicing structures, appurtenances, and measures. (*U.S. Soil Conserv. Serv.* 1970)

Travel influence zone

1. U.S. Forest Service usage. Areas comprising existing or anticipated significant public outdoor recreational occupancy, use, and enjoyment along existing and planned overland routes of travel; areas in and around existing or planned developed recreation sites. These are areas in which beauty of the landscape and other aesthetic values are key management considerations and are an important part of the outdoor environment. These areas offer significant opportunities for existing, planned, or anticipated recreational use and enjoyment by people visiting or traveling through the zone.

Includes area immediately adjacent to and surrounding developed or planned sites where people may stroll.

Comprises areas along existing or planned overland routes of public travel where the immediate scenic frame or foreground is subject to close scrutiny. Other foreground and backdrop areas should be recognized in zones with appropriate management emphasis on beauty and other aesthetic values. Roads, trails, railroads, tramways, and ski lifts are included as overland travel routes. This does not include work roads, trails, and other overland routes where public travel is only occasional.

Lands which have these characteristics and are also significantly influenced by considerations related to water will be included in the **water influence zone**. (*U.S. Forest Serv., FSM 8223.2, Dec. 1974*)

2. The area adjacent to selected or proposed highways, roads and trails subject to special management measures to maintain or improve the aesthetic quality for the traveler. (*U.S. Forest Serv. Region 9, 1975*)

Trophic level

In biotic communities organisms

whose food is obtained from plants by the same number of feeding steps in a **food chain** are said to belong to the same "trophic level". Thus green plants occupy the first trophic level, plant-eaters (i.e., herbivores), the second level, the carnivores (i.e., meat eaters) which eat the herbivores the third level, and secondary carnivores (i.e., carnivores which eat other carnivores) the fourth level. (*Odum 1953*)

Turbidity

Defined as the capacity of materials suspended in water to scatter light. It is measured in arbitrary Jackson turbidity units (JTU). Highly turbid water is often called "muddy", although all manner of suspended particles contribute to turbidity. (*Feth 1973*)

Type conversion

The conversion of one type of vegetation cover to another, e.g., the conversion of brush or forest covered lands to grass as for grazing purposes or the conversion of a white fir forest to a ponderosa pine forest. (*C.F.S.*)

U

Unacceptable risk. See **Risk**, unacceptable.

Unavailable forage

Forage which cannot be grazed by livestock. (*Amer. Soc. Range Manage. 1964*)

Uncertainty

1. Decision making in which there is no objective basis for assigning numerical probability weights to the different possible outcomes or there is no way to describe the possible outcomes. (*U.S. Forest Serv. 1972B*)

Under the Bayesian school of thought the distinction between risk and "uncertainty" is not useful and in fact may not exist. In any practical analysis all uncertain situations are assigned probability distributions, either

explicitly or implicitly by the selection of the analysis method, whether or not the true probability distribution is known. A probability distribution is selected for analysis purposes based on experience, intuitive feelings, knowledge, and the lack of knowledge. (*E.C.T.*)

Also see **Risk**.

Underprivileged groups. See **Disadvantaged groups**.

Understocking

Range management usage. Placing a number of animals on a given area that will result in underutilization of the available forage by the end of the planned grazing period. (*Amer. Soc. Range Manage. 1964*)

Understory

The trees and other woody species growing under a more or less continuous cover of branches and foliage formed collectively by the upper portions of adjacent trees and other woody growth. (*After Ford-Robertson 1971*)

Undesirable species

Range management usage. Plant species that are not desirable because they are unpalatable or low in **palatability**, injurious to animals, poisonous, poor stabilizers of soil and water, etc. (*Amer. Soc. Range Manage. 1964*)

Undeveloped land (Raw land)

A term of comparison sometimes used to contrast land which has been built upon (i.e., "developed") or subdivided in preparation for **development** with land on which such activities have not taken place (i.e., raw land). (*C.F.S.*)

Uneven-age management (Uneven-age silviculture)

The course of actions involved in maintaining a forest or stand, composed of intermingling trees that differ markedly in age. (*After Ford-Robertson 1971*)

Uneven-age silviculture. See Uneven-age management.

Uneven-aged stand (All-aged stand)

A forest stand composed of intermingling trees that differ markedly in age.

By convention, a minimum range of 10 to 20 years is generally accepted, though with **rotations** of less than 100 years, 25 percent of the rotation period may be the minimum. (*Ford-Robertson 1971*)

Unique resource (Irreplaceable asset)

1. A resource which is not duplicated anywhere. (*After Webster 1963*)
2. A resource for which no equal (although different) resource in kind

or excellence exists. (*After Webster 1963*)

3. The ability to produce or replicate facilities producing final consumption goods to gratify given tastes will lie at the base of the distinction between "producible" and "irreplaceable" assets. Irreplaceability, of course, will be a function of the closeness of substitutes in final consumption. With this as a point of departure, at least three classes of "irreplaceable assets" can be distinguished. One would be "gifts of individual genius" such as the work of Leonardo da Vinci or Rembrandt. A second might be called "gifts of collective genius", represented by the cultural antiquities of Egypt, Greece, and Rome, among others. Finally, we have the "gifts of nature", namely the accidents of **geomorphology**, biological evolution, and ecological **succession**.

In the latter we differentiate between natural endowments as factors of production, or intermediate goods, that are transformed through some production technology either into other goods in process or into final consumption goods, on the one hand, and natural endowments that directly give rise to stimuli eliciting satisfaction in an ultimate consumption of final-good sense, on the other. If a natural resource is used as a good in process, technology may provide a wide spectrum of substitutes for the particular input without significantly altering the final product either in appearance or performance. (*Krutilla, et al. 1972*)

Unique species. See **Species, unique**.

Unit. See **Planning unit**.

Unit plan

U.S. Forest Service usage. The plan for a specifically identified **planning unit**.

Unit planning

The activity of developing a com-

prehensive general long-range plan for a planning unit. (*W.W.*)

Universal soil loss equation. See **Soil loss equation.**

Unpalatable species

Range management usage. Species that are not readily eaten by animals. (*Amer. Soc. Range Manage. 1964*)

Unsuitable range. See **Range, unsuitable.**

Urban and built-up land and (Urban and built-up areas)

1. "Urban and built-up areas." Cities, villages, and built-up areas of more than 10 acres; industrial sites (except strip mines, borrow and gravel pits); railroad yards; cemeteries; airports; golf courses; shooting ranges; institutional and public administration sites; and similar kinds of areas. Road and railroad acreage is included, and intermingled Federal acreages may be included. Farmland acreage inside city and village limits is not included. (*U.S. Dep. Agric. 1967*)

2. Areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and such isolated units as mills, mines, and quarries, shopping centers, and institutions.

Small blocks of land of less intensive or nonconforming use isolated in the midst of built-up areas are generally included in this category. Agricultural, forest, or water area on the fringe of urban and built-up areas are not included, except where they are part of low-density urban development. The "urban and built-up land" category takes precedence over others when the criteria for more than one category are met. Thus, residential areas that have sufficient tree cover to meet forest land criteria will be placed in the residential category. (*Anderson,*

et al. 1972)

Also see **Urban land.**

Urban forestry

1. The practice of forestry in an urbanized environment. (*Andresen 1974*)

2. A specialized branch of forestry that has as its objective the cultivation and management of trees in urban areas and the evaluation of their contribution to the physiological, sociological, psychological (and sometimes economic) well-being of urban society. (*After Andresen 1974, citing Soc. Amer. For., Urban For. Work. Group,*

Urban fringe. See **Urbanized area.**

Urbanized area

U.S. Bureau of the Census usage
An urbanized area consists of a central city, or cities, and surrounding closely settled territory. The specific criteria for the delineation of an urbanized area are as follows: (1) a central city of 50,000 inhabitants or more; or two cities (i.e., cities with contiguous boundaries and constituting, for general social and economic purposes, a single community) with a combined population of at least 50,000. (2) surrounding closely settled territory, including incorporated places of 2,500 inhabitants or more; or, incorporated places with fewer than 2,500 inhabitants, provided that each has a closely settled area of 100 housing units or more; or, parcels of land normally less than one square mile in area having a population density of 1,000 inhabitants or more per square mile.

An urbanized area is sometimes divided into the "central city (or cities)" and those in the remainder of the area or the "urban fringe." The central city category consists of the cities, having 250,000 inhabitants or more, named in the title of the urbanized area.

The urbanized area can be characterized as the physical city as distinguished from both the legal city and

the metropolitan community. Generally, urbanized areas are smaller than and in most cases are contained in **standard metropolitan statistical areas** (SMSA). However, in a few instances, the fact that the boundaries of SMSA's are determined by political lines, and those of urbanized areas by the pattern of urban land use, means that there are small segments of urbanized areas which lie outside SMSA's. In general, then, urbanized areas represent the thickly settled core of the SMSA's, with the exceptions noted above. (*After U.S. Bur. Census 1971*)

Urban land

1. Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial, or recreational purposes. (*U.S. Forest Serv. 1972B*)

2. U.S. Soil Conservation Service usage. An area so altered or obstructed by urban works or structures that identification of soils is not feasible.

A **miscellaneous land type** mapping unit of the Soil Conservation Service. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Urban and built up land**.

Urban planning (City planning)

In its common usage "urban planning" is equivalent to **city planning**.

However, a distinction is sometimes made between the use of the two terms. "City planning" can refer just to planning activities that take place within or at the level of a specific city boundary. "Urban planning" can be used to refer to planning for areas which are in predominantly urban uses but which are larger in extent than a single city's boundaries. (*C.F.S.*)

Urban sprawl

A term used to describe the irregular and often poorly planned spreading of urban development into adjoining land areas. Many suburban residential developments are examples of urban sprawl. (*Sesco, et al. 1973*)

Use (Utilization)

Range management usage. The proportion of current year's **forage** production that is consumed or destroyed by grazing animals.

The putting of range to a purpose by animals such as grazing, bedding, shelter, trailing, watering, etc. (*Amer. Soc. Range Manage. 1964*)

Use, allowable

Range management usage. The degree of use estimated to be proper until proper use is known. Forty or fifty percent of the annual growth by weight is often used as a rule-of-thumb on ranges in good or excellent condition.

The amount of **forage** planned to be used to accelerate range rehabilitation. (*Amer. Soc. Range Manage. 1964*)

Use capability (Capability)

G.A. Hills usage. The first of Hills' three-level system for land evaluation. The process begins with evaluation for "use capability" based upon inherent usability potentials, then to evaluation for "use suitability" on the basis of management level potentials and finally to "use feasibility" evaluation on the basis of usability under present and forecasted socio-economic conditions. (*After Belknap and Furtado 1967*)

Also see **Capability**.

Use, degree of

Range management usage. Utilization or consumption of plant growth in respect to weight. It may be expressed in qualitative terms such as unused, slight, moderate, full, close, severe, over, extreme, destructive, etc., or as percent of weight for either an individual plant or the vegetation as a whole. (*Amer. Soc. Range Manage. 1964*)

Use district

A section of a city designated by a

zoning ordinance that prescribes the use of its land and the type and characteristics of the structures that may be placed on it.

The most common form of zoning in the United States is that in which "use districts" are designated (e.g., light manufacturing, commercial, single-family residential) and only the permitted use or a "higher" one is allowed. Thus in an area zoned for heavy industry, all other uses would theoretically be permitted (though there are some exceptions to this under the principle of **exclusive zoning**), whereas in an area of single-family residences, no other uses are likely to be permitted. (*Abrams 1971*)

Use factor

Range management usage. An index to the grazing use that is made of **forage** species, based on a system of **range management** that will maintain the economically important forage species. (*Amer. Soc. Range Manage. 1964*)

Use feasibility (Feasibility)

G.A. Hills usage. The third of Hills' three-level system for land evaluation. The process begins with evaluation for "use capability" based upon inherent usability potentials, then to evaluation for "use suitability" on the basis of management level potentials, and finally to "use feasibility" evaluation on the basis of usability under present and forecasted socio-economic conditions. (*After Belknap and Furtado 1967*)

Also see **Feasibility**.

Use, full

Range management usage. The maximum use that can be made of a range during a grazing season without inducing a downward trend in **range condition**. (*Amer. Soc. Range Manage. 1964*)

Use, Non- (Non-utilization)

Range management usage. Lack of

the exercise (temporarily) of a **grazing privilege** on grazing lands.

An authorization to refrain, temporarily, from placing livestock on public ranges without loss of preference for future consideration. (*Amer. Soc. Range Manage. 1964*)

Use, nonconforming

A building or use that is inconsistent with a **use district's** zoning regulations. If erected after the enactment of the ordinance it may be ordered removed. If in being before the enactment it may continue in use, but a new nonconforming or different nonconforming use may not be substituted. Nor is its extension or enlargement permissible if the ordinance so provides. Many ordinances permit the rebuilding of the nonconforming premises when destroyed by fire. Once the use is abandoned, however, the right to its restoration falls, and the future use of the premises must conform to the zoning. Some states allow for the abatement of such uses at the end of a prescribed and usually lengthy period of time (i.e., use of **time zoning**). (*Abrams 1971*)

Use, over-

Range management usage. Utilizing an excessive amount of the current year's growth which, if continued, will result in range deterioration or overgrazing. (*Amer. Soc. Range Manage. 1964*)

Use, pre-existing

A land use that does not conform to a **zoning ordinance** but that existed before the enactment and that therefore may not be banned until its abandonment. Sometimes the "pre-existing use", if a nuisance, can be abated by court action. In some jurisdictions "pre-existing uses" have been banned after the lapse of a reasonable period equivalent to a prescribed "depreciation period" or amortization of its use by **time zoning**. (*Abrams 1971*)

Use, proper (Proper utilization)

Range management usage. The degree and time of use of current year's growth which, if continued, will either maintain or improve the range condition consistent with conservation of other natural resources. (*Amer. Soc. Range Manage.* 1964)

Use suitability (Suitability)

G.A. Hills usage. Classification based upon the degree to which a unit, in its present condition, can respond to specific management practices. (*Belknap and Furtado* 1967)

The capacity of a unit in its present condition to respond to an assumed management practice. (*Belknap and Furtado* 1967)

The relative ability of a specific area in its present condition to produce specific goods and services. (*Hills, Love and Lacate* 1970)

The second of Hills' three-level system for land evaluation. The process begins with evaluation for "use capability" based upon inherent usability potentials, then to evaluation for "use suitability" on the basis of management level potentials, and finally to "use feasibility" evaluation on the basis of usability under present and forecasted socioeconomic conditions. (*After Belknap and Furtado* 1967)

Also see **Suitability**.

USGS.

Geological survey, U.S. Department of Interior.

Utilitarianism

A political philosophy based on the principle of "the greatest good of the greatest number". Public policy ought to be aimed at maximizing utility (that is, the maximization of pleasure for the maximum number of citizens).

The notion has been ridiculed on the grounds that no objective assess-

ment of utility is possible. (*O'Connell* 1974)

Also see **Utility theory**.

Utility

The usefulness or satisfaction causing qualities of a good or service. (*E.C.T.*)

Also see **Utility theory**.

Utility theory

1. A theory of valuation according to some measure of individual preferences or intrinsic usefulness and satisfaction causing qualities (utility) developed in the study of welfare economics. The valuation can occur either in **cardinal units** of utility (called **utils**) or as a comparison to other available goods given by **indifference curves**. An indifference curve is a delineation of all combinations of two goods with which an individual would be equally pleased (indifferent between). (*E.C.T.*)

2. "Non-market good" valuation usage. In attempting to place a value on goods which are not traded in the **marketplace**, **proxy values** can be derived by developing indifference curves between the non-market good and a good with a well established price. (*E.C.T.*)

3. Decision theory with **uncertainty** usage. In choosing among alternatives where the outcome of each alternative is uncertain, each possible outcome is weighted by its probability of occurrence and a **cardinal value** of the outcome's **utility** should it occur, to obtain an expected utility value for each alternative. The alternative with the highest expected utility is chosen. (*After Mac Crimmon* 1968)

Utilization. For range management usage see **Use**.

Util. See **Utility theory**.

V

Valid mining claim. See **Mining claim**, **valid**.

Value added

For a given enterprise, the **market value** of goods completed, less the cost of materials purchased from others.

Value, amenity. See **Amenity**.

Value judgement

A more or less subjective opinion about the worth (e.g., good, evil, beautiful, desirable) of a thing, action or entity (even when evaluators protest their lack of prejudice). (*Webster 1963*)

Values (Value system)

1. The particular (frequently subjective) point of view of an individual or the common point of view of a group on an issue, way of life, or concerning the worth of things or experiences. (*C.F.S.*)

2. An individual or collective conception of that which is desirable. This conception usually has both emotional and symbolic components. Values may range from those that are subjectively meaningful to a given individual to those that are shared **cultural norms**. They influence the selection of the means and ends of actions, and they serve as criteria by which objects or actions are evaluated. (*O'Connell 1974*)

Also see **Value judgement**.

For economic usages see **Market value**, **Non-market good valuation**, and **Proxy value**.

Value systems. See **Values**.

Variance (Zoning variance)

1. A license to do some act contrary to the usual rule. (*U.S. Bur. Outdoor Recreation 1974*)

2. The granting of relief from the terms or conditions of a building or

zoning law by a public agency vested with the power to authorize it. It may be given when the application of the law creates unnecessary hardship; where equally safe methods or materials may be used; where there are practical difficulties in meeting the existing requirements literally; or where the deviation or exception would not affect substantial compliance with the regulations and not threaten health or safety. (*Abrams 1971*)

Also see **Special exception**.

Vegetation cover type. See **Cover type**.

Vegetation type

A plant community with distinguishable characteristics. (*Soil Conserv. Soc. Amer. 1970*)

Also see **Cover type**.

Veto group

A pressure group that is sufficiently powerful to block any policy or law that it considers inimical to its interests. (*O'Connell 1974*)

Viewer inferior. See **Observer inferior**.

Viewer normal. See **Observer normal**.

Viewer superior. See **Observer superior**.

View landscape (Visual landscape)

A landscape which due to its juxtaposition with areas of human use is vulnerable to critical observation by various segments of the public. (*A.W.M.*)

Virgin forest

1. Natural forest virtually uninfluenced by human activity. (*Ford-Robertson 1971*)

2. A mature or overmature forest essentially uninfluenced by human activity. (*Soil Conserv. Soc. Amer. 1970*)

Visible area

The ground or vegetation thereon

that can be directly seen from a given lookout point under favorable atmospheric conditions. (*U.S. Forest Serv. 1972B*)

Visitor carrying capacity. See **Carrying capacity-recreation, economic.**

Visitor day

The use of an area for a total of 12 person-hours by one or more people, either continuously or spread over several visits. (*E.C.T.*)

Visual character subtype (Character subtype, Visual subtype)

U.S. Forest Service, Visual Management System usage. Areas of significant size and visual difference within **visual character type** units—e.g., steep mountain lands, foothill lands, rolling plateau lands.

Subdivisions of “visual character types” which are significantly different in visual characteristics from each other.

“Visual character subtypes” are delineated when a larger “visual character type” unit is too broad or has too great a visual character diversity to provide a logical frame of reference to usefully classify physical features.

“Subtype” units are also used to identify those portions of major character types having distinctive or outstanding common features. (*U.S. Forest Serv. 1974B*)

Also see the related terms of the visual management system, **Visual character type** and **Visual landscape character.**

Visual character type (Character type, Visual type)

U.S. Forest Service, Visual Management System usage. A large area of land that has common distinguishing visual characteristics of landform, rock formations, water forms and vegetation patterns. (*U.S. Forest Serv. 1974B*)

The “visual character type” con-

cept and the types of land units it produces should be about the same as **morphological region** and **physiographic regions.** (*C.F.S.*)

“Visual character type” units are used as a frame of reference for classifying the physical features of a given area as to their degree of scenic quality. (*U.S. Forest Serv. 1974B*)

Also see the related terms of the visual management system **Visual character subtype** and **Visual landscape character.**

Visual landscape. See **View landscape.**

Visual landscape character (Characteristic landscape)

U.S. Forest Service, Visual Management System usage. The overall impression created by a landscape’s unique combination of visual features (such as land, vegetation, water, structures) as seen in terms of form, line, color and texture. (*U.S. Forest Serv. 1973*)

The naturally established landscape being viewed as visually represented by the basic vegetative patterns, **land forms**, rock formations and water forms which are in view. (*U.S. Forest Serv. 1974B*)

A “visual landscape character” unit usually makes up a small portion of a **visual character subtype**, depending upon how much of the subtype unit can be viewed at one time. (*After U.S. Forest Serv. 1974B*)

Visual quality objective

U.S. Forest Service Visual Management System usage. “Visual quality objective” should more appropriately be called “visual quality goals” as per the definition of **goals.** Contrast the definition of goal with that of **objective.**

A set of measurable goals for the management of forest visual resources. The stated goals of this visual management system are: (1) preservation,

(2) retention, (3) partial retention, (4) modification, and (5) maximum modification. Except for "preservation" each goal describes a different degree of acceptable alteration of the natural landscape based upon the importance of aesthetics.

"Preservation" allows only natural ecological changes. "Retention" allows management activities which are not visually evident. "Partial retention" allows management activities which are visually subordinate to the **characteristic visual landscape**. "Modification" allows management activities that may visually dominate the original "characteristic visual landscape", but, when vegetation and **land forms** are altered, which must use the form, line, color, texture and/or **scale** of that landscape for its visual characteristics. "Maximum modification" allows vegetation and land form altering management activities that dominate the "characteristic visual landscape" in the **foreground** and **middleground** but which have the same visual characteristics as the surrounding area when seen as **background**. Two additional short-term management goals may be required. The first, "rehabilitation", is used to upgrade landscapes containing visual impacts which do not meet the quality objectives set for that particular area. The second, "enhancement", is for landscapes having a potential for greater natural-appearing variety. Once one of the short-term goals is attained, one of the five quality goals is then applied. (*After U.S. Forest Serv. 1974*)

Visual resource

The composite of basic terrain, geologic features, water features, vegetative patterns, and land use effects that typify a land unit and influence the visual appeal the unit may have for visitors. (*Sandpoint Zone Plann. Team 1974*)

Visual sensitivity level (Sensitivity level)

U.S. Forest Service, Visual Management System usage. A three-level rating system used to delineate areas receiving different amounts of exposure (present or potential) to user groups with differing **attitudes** towards changes in scenic quality (such as might occur as a result of management activities).

The system initially classifies all travel routes, **special interest areas** and water bodies into areas of primary and secondary aesthetic management importance on the basis of their national importance, number of users, duration of use and area size. The system next uses the assumptions that aesthetic quality will be of major concern to recreational users and minor concern to functional users of forest areas (such as daily commuters and loggers) as the other basis for classifying the entire planning area into the three sensitivity levels. (*After U.S. Forest Serv. 1974*)

Visual subtype. For U.S. Forest Service usage see **Visual character subtype**.

Visual variety class (Variety class)

U.S. Forest Service Visual Management System usage. A classification system for establishing three visual landscape categories according to the relative importance of the visual features—i.e., **landforms**, vegetation patterns, stream or lake water forms and rock formations. The class A ("distinctive") category contains those landscape features of unusual or outstanding visual quality, and, that are usually not common in the **visual character type** or **visual character subtype**. The class B ("common") category contains those landscape features which tend to be common throughout the **visual character type** or **subtype** and thus are not of outstanding visual quality. The class C ("minimal") category contains those areas with few distinguishing landscape features—including all areas

not classed as A or B.

This classification system is based on the premise that all landscapes have some visual values, but those with the most variety or diversity of visual features have the greatest potential for being or attaining high scenic value. (*After U.S. Forest Serv. 1974*)

Visual vulnerability

1. The degree to which man-made changes might be seen in the landscape and their potential for degradation

(of scenic quality)—in essence, the landscape's resistance or susceptibility to visual changes. (*Litton 1974*)

2. The susceptibility of an object or changed condition to critical evaluation as a consequence of its location in a position where it can be readily seen by the public.

As applied to landscapes it means their susceptibility to criticism (pro or con) as a consequence of their availability to public observation. (*A.W.M.*)

W

Wants. See Needs.

Warm-water fishery

Stream and lake waters which support fishes with a maximum summer water temperature tolerance of about 80 degrees Fahrenheit. Bluegills, perch and largemouthed bass are examples. (*After U.S. Forest Serv., FSM 2605, Sept. 1974*)

Water bloom. See Bloom.

Water influence zone

1. U.S. Forest Service usage. Areas comprising existing or anticipated significant public outdoor recreational occupancy, use, and enjoyment along streams and rivers and around lakes, reservoirs, and other bodies of water, areas in which uses and activities are oriented to overwater travel and outdoor recreation. (*U.S. Forest Serv., FSM 8223.1, Oct. 1973*)

These are areas in which beauty, aesthetic values, and water quality, and usefulness are key management values and an important part of the environment and offer significant opportunities for existing, anticipated, or planned use and enjoyment by persons visiting or traveling through the zone.

Includes areas immediately adjacent to and surrounding developed or planned sites along the banks and shores where people may fish or stroll. Comprises areas adjacent to the water along

overwater travel routes and water-sports use where the immediate scenic frame and foreground are subject to close scrutiny. Other foreground and backdrop areas should be recognized in other zones with appropriate management emphasis on beauty and esthetic values. Live and intermittent streams and waters where developed facilities for occupancy and use do not exist, or are not anticipated or planned, or areas which are seldom visited for recreation and enjoyment, are usually not included. Such areas should be recognized in other management zones with due consideration given to the aquatic and related wildlife habitat and to soil and water values. (*U.S. Forest Serv., FSM 8223.1, Dec., 1974*)

2. The areas adjacent to lakes and selected streams subject to special management measures to protect water quality and maintain or improve aesthetic quality. (*U.S. Forest Serv. Region 9 1975*)

Water pollution

Any substance or energy form (heat, light, noise, etc.) which alters the state of a body of water from what would naturally occur. Especially associated with those altered states which human value judgements have decreed as bad. (*E.C.T.*)

Also see **Pollution.**

Watershed (Drainage basin, Catchment basin, River basin)

1. United States usage. The total area above a given point on a stream that contributes water to the flow at that point.

The entire region drained by a waterway or which drains into a lake or reservoir. (*After SESCO, et al. 1973*)

2. British usage. The topographic dividing line from which surface streams flow in two different directions; the line separating two contiguous drainage areas. (*Stamp 1961*)

Watershed management

1. The management of all the natural resources of a watershed to protect, maintain, or improve its water yields. (*Satterlund 1972*)

Watershed protection

Watershed protection involves a combination of complementary practices of land treatment and structural works to maintain or improve total yield, quality, stability of flow of surface and subsurface water and prevention of damage and loss due to excessive and uncontrolled runoff, flooding, salination, and siltation. (*Eisner 1969*)

Water table (Groundwater table)

The upper surface of the groundwater or that depth below which the soil is saturated with water. (*Soil Conserv. Soc. Amer. 1970*)

Water table, perched (Perched groundwater table)

The upper surface of a local zone of soil water saturation held above the main body of groundwater by an impermeable layer or stratum, (usually clay) and separated from the main body of groundwater by an unsaturated zone. (*Soil Conserv. Soc. Amer. 1970*)

Watertype. For G.A. Hills' land classification system usage, see **Landtype**.

Water year

The 12-month period, October 1 through September 30, designated by the calendar year in which it ends (used with streamflow data and analyses). (*Soil Conserv. Soc. Amer. 1970*)

Water yield

1. The runoff from a watershed, including groundwater outflow. (*U.S. Forest Serv. 1972B*)

2. Water yield is the precipitation minus the evapotranspiration. (*U.S. Forest Serv. 1972B*)

Weather (Meteorological condition)

The state of the atmosphere at a definite time and place with respect to air temperature, humidity, wind, precipitation, cloudiness, etc. (*Webster 1963*)

Also contrast with **Climate**.

Weed cutting (Weeding)

Cutting made in a young stand, not past the sapling stage, to free the small trees from weeds, brush, chaparral, vines, sod-forming grasses, or other competing vegetation. (*U.S. Forest Serv., FSM 2471 R-3*)

Weeding. See **Weed cutting**.

Weighting

1. Assigning numbers to express the relative importance of items in a group or series under consideration. (*After Webster 1963*)

2. The assignment of numerical values to resource yields when their values can not be directly compared by existing techniques for quantification on some measurement scale. The assigned numerical values are usually referred to as "weights" or "multipliers".

As a technique, weighting is usually done according to some more or less objective sense of the relative importance of the different types of resource yields.

While weightings are usually added (i.e., **additive weighting**) to obtain a measure of the total social value of re-

source uses or resource yield mixes for planning areas, they may also be multiplied or divided (or some combination of these processes) to facilitate decision making. (*C.F.S.*)

Welfare. See **General welfare.**

Wetlands

1. Areas that are permanently wet, or intermittently water covered, such as swamps, marshes, bogs, muskegs, potholes, swales, glades, and overflow land of river valleys. Large, open lakes are commonly excluded, but many kinds of ponds, pools, sloughs, holes, and bayous may be included. (*Veatch and Humphrys 1966*)

2. Inland usage. Any area that is more or less regularly wet or flooded. Where the water table stands at or above the land surface for at least part of the year.

3. Coastal usage. Land types such as salt marshes, and brackish marshes subject to saline and/or tidal influences. (*Durrenberger 1973*)

4. Lowlands covered with shallow and sometimes temporary or intermittent waters. Shallow lakes and ponds, usually with emergent aquatic vegetation (such as reeds or cattails) as a conspicuous feature, are included in the definition, but the permanent waters of streams, reservoirs and deep lakes are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist-soil dependent vegetation. (*Shaw and Fredine 1956*)

Wet meadow

A meadow where the surface remains wet or moist throughout the summer, usually characterized by sedges and rushes. (*Amer. Soc. Range Manage. 1964*)

Wild and Scenic Rivers Act (82 Stat. 906; 16 U.S.C. 1271-1273, 1274(A), 1275(A))

Declares that it is a policy of the

United States that certain selected rivers of the nation which, with their immediate environments, possess outstanding remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. Implements this policy by instituting a National Wild and Scenic Rivers System, by designating the initial components of that system, and by prescribing the methods by which and standards according to which additional components may be added to the system from time to time. (*After U.S. Forest Serv. 1974*)

Wilderness

1. Popularly, any tract uncultivated and uninhabited by human beings. (*Ford-Robertson 1971*)

2. "Wilderness area". Undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least 5000 acres or is of sufficient size as to make practical its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or features of scientific, educational, scenic, or historical value. (*Wilderness Act 1964*)

A tract of land, including interior bodies of water, open to overnight public use and entry by foot, horseback, or hand-propelled vessel; primarily in public ownership, in the continental U.S.; not less than 100,000

acres in extent; containing no roads constructed for passenger car traffic in mountainous terrain, or suitable for passenger car traffic in desert or plains; existing as a single unit with boundaries reasonably free of indentation; without interruption by on-site influence, except that—effects of domestic livestock are acceptable; effects of selection logging before 1920 are acceptable east of the 98th meridian; ecological effects of fire suppression are acceptable in all areas. (*Calif., Univ., Wildland Res. Cent.* 1962)

A continuous stretch of country preserved in its natural state, open to lawful hunting and fishing, big enough to absorb a two weeks' pack trip, and kept devoid of roads, artificial trails, cottages, or other works of man. (*Leopold* 1921)

An area where the earth and its community of life are untrammelled by man, where man himself is the visitor who does not remain. (*Wilderness Act* 1964)

In common usage, "wilderness" refers to those backcountry types of wildlands which show no obvious evidence of present or previous human uses other than foot or pack animal trails. Some use the terms primitive and wilderness interchangeably to refer to all areas displaying no obvious evidence of present or previous human uses—other than foot or pack animal trails. Others make a distinction between the two, using "primitive" to refer to all areas possessing wilderness qualities and restricting the use of "wilderness" to only those portions of the larger primitive area which have officially been designated as "wilderness" areas. (*After A.W.M.*)

Wilderness Act (78 Stat. 890; 16 U.S.C. 1131-1136)

Establishes a National Wilderness Preservation System to be composed of Federally owned areas designated

by Congress as **wilderness areas**, and these shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness. (*After U.S. Forest Serv.* 1974)

Wilderness area. See **Wilderness**, definition. 2.

Wilderness study area

An area which has been placed under formal consideration for possible inclusion in the wilderness area system. A new study area in a National Forest is removed from standard management and planning considerations until its status as a wilderness area is determined. After study such areas will be classified as either **nonselected roadless areas** or **roadless and undeveloped areas**. (*U.S. Forest Serv., FSM* 8261.05, Apr., 1974)

Also see **Roadless and undeveloped areas** and **Nonselected roadless area**.

Wildfire (Forest fire)

A free-burning fire.

Any fire other than a **controlled burn** or a **prescribed burn**, occurring on **wildland**. (*Ford-Robertson* 1971)

Any fire other than one intentionally set for management purposes and whose extent is confined to a predetermined area on wildlands. (*C.F.S.*)

Wildland

1. Non-urban areas that are not intensively managed and manipulated. They include most managed forests but not city parks with their exotic plants, "manicured" lawns, and sprinkler systems. The term is not exact because it includes lands that are under management and are not truly wild. Through long usage it has come to ap-

ply to lands that are sparsely settled and present a fairly natural appearance. Forests, deserts, mountains, grasslands, and other extensive lands are normally included. (*Wagar 1964*)

This term is most often used as one of several terms of comparison contrasting the differing degrees of utilization and alteration of land which occur—e.g., urban lands, agriculture lands and wildlands. The dividing lines between these states cannot be defined in any generally acceptable quantitative terms. The only firm sense of differentiation between these terms exists when they are used to describe broadly contrasting natures and intensities of land utilization. “Wildlands” are simply those natures and intensities of use on the least utilized and altered side of the continuum from totally developed to completely untouched. (*C.F.S.*)

2. Lands unoccupied by crops, pastures, urban, residential, industrial or transportation facilities.

Lands over which man has not extended his complete and permanent domain with his bulldozers, plows and asphalt spreaders. (*After Calif. Univ., Wildland Res. Cent. 1959*)

3. Uncultivated land, except fallow lands. (*Ford-Robertson 1971*)

4. Land that is uncultivated or unfit for cultivation. (*Webster 1963*)

Wildlife

1. U.S. Forest Service usage. All nondomesticated mammals, birds, reptiles, and amphibians living in a natural environment, including both **game species** and nongame species, whether considered beneficial or otherwise.

Animals, or their progeny, which once were domesticated but escaped captivity and are running wild (i.e., **feral animals**), such as horses, burros, and hogs, are not considered to be wildlife. (*U.S. Forest Serv., FSM 2605, Sept. 1974*)

2. Undomesticated vertebrate animals, except fish, considered collectively. (*Soil Conserv. Soc. Amer. 1970*)

3. Generally, all non-domesticated animal life. (*Ford-Robertson 1971*)

4. More particularly, a loose term that includes non-domesticated vertebrates especially mammals, birds and fish and some of the higher invertebrates (such as crabs, crayfish, etc.) (*Ford-Robertson 1971*)

5. Living things that are neither plant, human nor domesticated; especially the mammals, birds and fishes that are hunted by man for sport or food. (*Webster 1963*)

Wildlife and Fish Habitat System

U.S. Forest Service usage. This system protects and improves wildlife and fish habitat with special emphasis on **threatened** and **endangered species**. Management of wildlife and fish habitats is closely coordinated with the states because they control wildlife and fish populations. This coordination includes (1) close working relations among National Forest, State, and private land managers; (2) cooperative forestry programs designed to assist non-Federal land managers; and (3) research programs that define environmental requirements of fish and wildlife and provide management alternatives through which these requirements can be attained.

One of the six “systems” established by the U.S. Forest Service to have a systematic, orderly way to view and evaluate its many diverse but interrelated activities. The Forest Service has developed this approach to better respond to the mandates of the **Forest and Rangeland Renewable Resources Planning Act of 1974**. It has grouped its various programs into these six “systems”, each of which incorporates all the activities concerned with developing and managing a specific re-

source. (*After U.S. Forest Serv. 1974A*)

The six "systems" are: **Land and Water, Timber Resource, Outdoor Recreation and Wilderness, Rangeland Grazing, "Wildlife and Fish Habitat", and Human and Community Development.**

Wildlife land

U.S. Soil Conservation Service usage. Land and water managed primarily for fish and wildlife. Wildlife may be a secondary use of land with cropland, rangeland, woodland, etc., as the primary use. (*U.S. Soil Conserv. Serv. 1970*)

Wild river area

Wild and Scenic Rivers Act usage. Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America. (*After U.S. Forest Serv. 1974*)

Willingness-to-pay

An economic concept used either in **non-market good valuation** or when the prevailing price of a good or service is thought to be different from its true value to an individual or society. It refers to the price an individual would be willing to pay rather than be deprived of the good or service.

In precise economic theory the validity and applicability of "willingness-to-pay" is dependent on who is assigned initial ownership rights to the good or service being evaluated. (*E.C.T.*)

Also see **Consumer surplus** and **Producer surplus.**

Wildfall

1. A tree or trees thrown or their stems broken off or other parts (branches, foliage, fruit, etc.) blown down by the wind. (*Ford-Robertson 1971*)

2. Any area on which (many of) the trees have been uprooted (i.e., **windthrown**) or broken by the wind. (*Ford-Robertson 1971*)

Windfirm

Trees able to withstand strong winds—i.e., able to withstand the force of wind without being uprooted (i.e., **windthrown**). (*Ford-Robertson 1971*)

Windthrow (Blow down)

1. Uprooted by the wind. (*Ford-Robertson 1971*)

2. Also used to refer to a tree or trees so uprooted. (*Ford-Robertson 1971*)

In forestry "windthrow" becomes particularly important in conjunction with the **clearcutting** system and **clearcutting logging** methods. Trees tend to develop root systems to support themselves against the forces they face. When either a new forest edge is created by logging or selected trees from a group are removed the remaining trees may face a significant increase in the force of the wind. The trees growing on the edge of a forest tend to shelter the interior trees, and trees in a group protect each other from the full force of the wind. If the remaining trees do not have root systems capable of absorbing this additional stress they will be blown down. (*E.C.T.*)

Woodland

U.S. Soil Conservation Service usage. Land used primarily for the production of adapted wood crops and to provide tree cover for watershed protection, beautification, etc. Does not include farmstead and field windbreak plantings. (*U.S. Soil Conserv. Serv. 1970*)

Working circle

A forest area organized for a particular objective and under one set of **working plan** prescriptions, and embodying one **silvicultural** system or a

designed combination of systems.
(*Ford-Robertson 1971*)

Working group

U.S. Forest Service usage. Those parts of a **working circle** that have the same general management prescriptions.

This designation may be applied to combinations of species, types, or sites, such as pine and hardwood working groups, mixed conifer and douglas-fir working groups, and site I-III and site IV-V working groups. In some working circles a working group is set up for areas where timber man-

agement is to be modified, such as in landscape management areas. (*U.S. Forest Serv., FSM 2412.5, May 1972*)

Working plan

1. A plan for managing a forest.
(*After Ford-Robertson 1971*)

2. The written, often printed and published management plan, aiming at continuity of policy and action, and both prescribing and controlling basic operations in a forest over a period of years. (*After Ford-Robertson 1971*)

WRC

Water Resources Council, U.S.

X

Xeric

1. Refers to a **habitat** characterized by dry conditions rather than **mesic** (moderate) or **hygric** (wet) conditions.
(*Hanson 1962*)

2. The nature of an organism

adapted to dry conditions. (*Dansereau 1957*)

Xerosere. See **Succession**, definition 1.

X section. See **Cross section**.

Y

Yarding

The operation of hauling timber from the stump to a collecting point.
(*Ford-Robertson 1971*)

Yarding, skyline (Skyline logging)

A method for moving logs to a central loading area by the use of overhead cable systems that lift at least one end of the log off the ground. (*After Ford-Robertson 1971*)

Z

Zonal soil. See **Soil horizon**, definition 2.

Zoning

In general, the demarcation of a planning area by **ordinance** into zones and the establishment of regulations to govern the use of the land (commercial, industrial, residential, type of residential, etc.) and the location, bulk, height, shape, use, and coverage of structures within each zone. (*Abrams 1971*)

Zoning, aesthetic

Zoning which regulates property in the interest of protecting aesthetic values.

The U.S. Supreme Court in the 1954 "Berman vs. Parker" case upheld this extension of the original legal justification for zoning powers with its finding that "It is within the power of the legislature to determine that the community should be beautiful as well as healthy." (*After Abrams 1971*)

Zoning, agricultural

Zoning which restricts land uses to agriculture and other low-density uses. (*After U.S. Bur. Outdoor Recreation 1974*)

Zoning, cluster (Residential planned development zoning, Planned unit development zoning)

1. A form of zoning that allows a developer to reduce his minimum lot size below the **zoning ordinance's** requirements if the land thereby gained is preserved as permanent **open space** for the community. (*Abrams 1971*)

2. Residential planned development zoning is zoning which allows landowners the opportunity to intensively develop one portion of their property while leaving the remaining portion in an undeveloped state.

"Cluster zoning". Instead of the developer covering his tract with equal-sized lots, the local government alters standard lot size regulations to permit tighter patterns of house groupings. This can save money for the developer; he builds the same number of housing units, but does not have to bulldoze as much or lay as much asphalt and service facilities. In exchange, the developer leaves from 40 to 60 percent of the land open and deeds it for common use of the residents.

Cluster zoning is a device for building open space into the everyday environment of residential subdivisions. Planned unit development (i.e., **cluster development**) uses this approach. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, conservation

Zoning which restrains development of unsuited areas such as steep slopes with fragile soils, areas of scenic beauty, and spaces with other natural values. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, development

A term used to refer to all types of

zoning which regulate **development**—i.e., types of land use which prominently alter or dominate the original open space of an area with built-up facilities such as buildings, streets and other paved areas, etc. (*C.F.S.*)

For example, **large-lot zoning** and **cluster zoning** are types of "development zoning". (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, Euclidean

Zoning of the type adopted by the city of Euclid, Ohio, and made famous in 1926 by the United States Supreme Court decision in village of Euclid vs. Ambler Realty Company, upholding the nation's first comprehensive zoning ordinance. The Euclid **zoning ordinance** restricted the location of trades, industries, apartment houses, two-family houses, single-family houses, the lot area to be built upon, the size and height of the buildings, etc. The court found these restrictions neither "unreasonable" nor "arbitrary." Since that time the term has come to describe the most common form of zoning in the United States, in which "use districts" are designated (i.e., light manufacturing, commercial, single-family residential) and only the permitted use or a "higher" one is allowed. Thus in an area zoned for heavy industry, all other uses would theoretically be permitted (though there are some exceptions to this under the principle of **exclusive zoning**), whereas in an area of single-family residences, no other uses are likely to be permitted. (*Abrams 1971*)

Zoning, exclusive use

A **zoning** regulation which permits only one type of use in a particular established zone or district. (*After U.S. Bur. Outdoor Recreation 1974*)

Zoning, flood plain

Zoning which prohibits and restricts development within **flood plains** to prevent property loss, to insure

public safety, and to enable the safe and natural flow of streams. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, forest (Forest use zoning)

Zoning which restricts land uses to forestry and related uses—e.g., timber production, watershed, Christmas tree farms, recreation, etc. (*C.F.S.*)

Zoning, land capability

Zoning which limits development in areas which are subject to natural land or water hazards. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, large-lot

Zoning which prohibits subdivision of land into individual parcels of less than a specified, relatively large lot size—e.g., 1 acre or more. (*C.F.S.*)

Large-lot zoning is used extensively to retard development. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning, natural resource

A blanket term used to refer to all zoning which restricts the uses that are made of **natural resource** lands so as to maintain the benefits which flow from their natural capacities, productivity or material contents. For example **floodplain zoning**, **agricultural zoning** and **forest zoning** are types of “natural resource zoning”. (*C.F.S.*)

Zoning, open space

Zoning which restricts land uses so as to retain **open space**. (*C.F.S.*)

“Open space zoning” includes **large-lot zoning** and **cluster zoning** (forms of **development zoning**) and **natural resources zoning**. (*U.S. Bur. Outdoor Recreation 1974*)

Zoning ordinance

A local law or regulation enacted by a city council or other similar body (working under the powers delegated to it by the state) which establishes the appropriate uses within a particular, designated area (i.e., a zone) and the location, bulk, height, shape, use

and coverage of structures, etc. within each zone. (*After Webster 1963 and Abrams 1971*)

Zoning, performance (Performance standard zoning)

Regulations providing general criteria for determining the acceptability of certain industries, land uses, and buildings as distinguished from specification standards or detailed requirements. This type of zoning does not bar an industry or use by name but admits any use, provided the particular requirements set for admission are met. (*Abrams 1971*)

Zoning, prohibition

Any of the class of zoning regulations which only allows certain types of use in certain kinds of areas. For example, flood plain zoning frequently permits only uses which do not need structures nor reduce the flood water storage capacity of such hazardous areas. (*C.F.S.*)

Zoning permit

An official finding that a planned use or structure complies with the zoning regulations or is allowed by the granting of a **special exception** or **variance**. No new development or substantial change of use can occur until such a permit is issued in a planning area regulated by **zoning ordinances**. (*After Abrams 1971*)

Zoning, spot

The designation of an isolated parcel of land for a use classification harmful to or inconsonant with the use classification of the surrounding area so as to favor a particular owner. The courts have held such zoning to be “unreasonable” and “capricious”. To avoid judicial invalidation, zoning of small areas can be enacted only when it is in furtherance of a **general plan** properly adopted by, and designed to serve the best interests of the community as a whole. This does not mean

that an entire city or county must be zoned at one time, but there must be uniformity in the class or type of building to which the zoning applies. (Abrams 1971)

Zoning, time

Restricting an existing **non-conforming use** within a **use district** to a specific period, upon the expiration of which it becomes illegal. Sometimes the time period's justification is referred to as "amortization of the use" and it is presumed to afford the non-conforming owner a reasonable number of years within which to recover his investment under the **pre-existing use**. (Abrams 1971)

Zoning variance. See **Variance**.

Zoological area

U.S. Forest Service usage. An area

which has been designated by the Forest Service as containing authentic, significant and interesting evidence of our American national heritage as it pertains to **fauna**. The areas are meaningful because they embrace animals, animal groups or animal communities that are natural and important because of occurrence, **habitat**, location, **life history**, ecology, environment, rarity or other features. (U.S. Forest Serv., FSM 2362.44, July 1973)

Areas of this type and all other **special interest areas** are identified and formally classified primarily because of their recreational values. Areas with similar types of values of scientific importance are formally classified as "research natural areas" (see **Natural area, research**). (W.W.)

Zooplankton. See **Plankton**.

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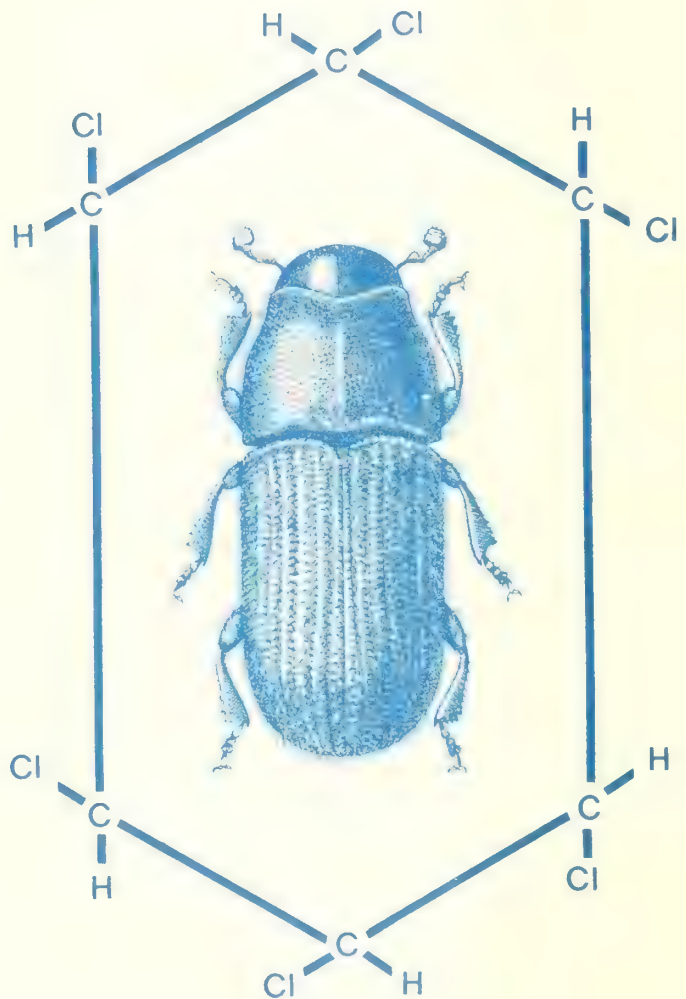
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LINDANE IN FORESTRY... a continuing controversy

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USDA FOREST SERVICE
GENERAL TECHNICAL
REPORT PSW-14 /1976

LINDANE IN FORESTRY...a continuing controversy

Thomas W. Koerber, compiler

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Use of the chlorinated hydrocarbon insecticide lindane to control bark beetles is controversial. Differences of opinion persist, even among knowledgeable entomologists, on whether use is justified in view of potentially harmful side effects. Effectiveness of lindane treatments, as employed in preventing tree mortality from bark beetles, is also in question. In seven papers, relevant information from many sources is reviewed by investigators who hold divergent views. The papers present data on the biological characteristics of lindane, its persistence in the environment and effects on both target and nontarget organisms. The place of lindane in a spectrum of forest management alternatives is presented together with arguments both for and against its continued use.

Oxford: 453--145.7x19.92 Scolytidae--414.12 Lindane.

Retrieval Terms: Bark beetle control; lindane; cyclohexane,1,2,3,4,5,6-hexachloro-(benzene hexachloride)gamma isomer.

Compiler

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PREFACE

The use of pesticides in resource management is a highly controversial issue. Arguments on the subject appear almost daily in technical journals, in the press, and in the proceedings of legislative bodies. Even well-informed persons do not agree on the best policy to follow. Meanwhile, pest management decisions are required on a day-to-day basis.

The use of chlorinated hydrocarbon pesticides, because of their persistence in the environment, has been particularly controversial. In November 1969, the Marak Commission on Pesticides and Their Relationship to Environmental Health recommended that the use of chlorinated hydrocarbon insecticides, including lindane,^{1/} be restricted to essential purposes and be replaced by safer alternatives whenever possible. The U. S. Department of Agriculture invited submission of views on the proposed restrictions (Federal Register, vol. 35, no. 148). Dr. Ralph C. Hall, then Chairman of the California Forest Pest Control Action Council^{2/} drafted a brief in support of continued use of lindane to control bark beetles in California forests. This statement was approved by the Executive Committee of the Council on October 22, 1970, and forwarded to the Director of the Pesticide Regulation Division of the Agricultural Research Service.

^{1/} The name "lindane" strictly denotes the gamma isomer of benzene hexachloride (BHC). As broadly used in this publication, "lindane" may refer either to the pure gamma isomer or to the gamma isomer content of a mixture of BHC isomers.

^{2/} The California Forest Pest Control Action Council was formed in 1951 in recognition of the need for close cooperation among land managers concerned with forest pest problems. Primarily an advisory and coordinating group, the Council sponsors a Statewide cooperative forest pest detection survey; publishes an annual report of forest pest conditions; studies, endorses, and supports desirable pest control actions; reviews control needs and programs; and provides a forum for the exchange of pest control information. The California State Board of Forestry has designated the Council as its official advisory group for forest insect, disease, and animal problems.

When the Insect Committee of the Council next met on November 18, some members objected to the content of the brief, and to the lack of consultation with the Insect Committee in its preparation. A resolution stating that the Insect Committee was not in support of the Executive Committee was passed and presented at the meeting of the full Council the following day. The resolution was tabled by the full Council on the grounds that too little time was available to discuss the issue properly.

A special meeting of the Insect Committee was held on February 3, 1971, to discuss the issue. Reports presenting both sides of the controversy and bringing together relevant information from scattered sources had been prepared by members of the Insect Committee. These reports were distributed to the members before the meeting so that those participating in the discussion were well informed on both sides of the issue and prepared to question or defend specific points of fact or opinion.

After a full day of discussion, the proposed resolution denying support to the recommendation of continued use of lindane was defeated by a vote of 21-20. An alternative resolution recommending the continued registration of lindane for control of bark beetles, wood borers, powder post beetles, ambrosia beetles, and termites, when noninsecticidal alternatives for control are not suitable, was then passed by a vote of 21-18. The full Council approved this resolution at its next regular meeting, November 1971.

In response to these proceedings, comprehensive tests were made to find alternatives for lindane against western bark beetles. The results, now in manuscript form, show that Dursban and Sevin are effective, though generally not comparable to lindane, in preventing attacks, and could be considered for use under certain conditions. Registration of these chemicals for use against bark beetles is expected in the near future.

The continuing demand for the reports prepared for the February 1971 Insect Committee meeting has prompted their publication here. They served as the basis of another brief supporting continued registration of lindane (submitted by the Council to the U. S. Environmental

Protection Agency in May 1972) and a minority report opposing continued use of lindane (submitted in February 1974). As of the date of this publication, lindane registration remains in effect.

This account of the Council's role in the lindane controversy is necessarily brief. Considerable interest has been shown in the process by which the Council handled the controversy. Therefore, details of the discussions, including copies of the various briefs, resolu-

tions, and minutes of the meetings, are available on request to the Project Leader, Forest Insect Research, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, CA 94701.

Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U. S. Department of Agriculture is implied.

Biological Characteristics of Lindane

Thomas W. Koerber

Abstract--Lindane is an effective insecticide against bark beetles. It is equally toxic to nontarget insects but much less toxic to mammals, birds, and plants. It is moderately stable in soil and bark, but animals and bacteria rapidly metabolize it to nontoxic products, thus preventing significant concentration in living animals and movement in food chains.

The biological properties of a chemical determine how it will affect the organisms that contact it, and how it will behave in the ecosystem. The differences in biological properties between chemicals dictate the differences in their behavior as toxicants and as environmental pollutants.

I consider the properties of an ideal insecticide to be these:

It must be highly effective against the target organism, so that a small dose will produce the desired effect.

It should be nonpersistent under field conditions, rapidly decomposing to nontoxic materials, unless persistence is required to meet the objectives of its use.

It should be immobile, not easily exported from the place of application either by physical means or in food chains.

It should be reasonably safe and not unpleasant to handle.

It should have solubility and stability characteristics that do not require exotic solvents, adjuvants, special mixing or application equipment, or special storage conditions.

Let us consider lindane in relation to the ideal insecticide.

Effectiveness--Lindane's toxicity to various bark beetles has been investigated in laboratory studies by Lyon (1959). He reported contact LD₅₀ values of 7.3 mg/kg for *Dendroctonus ponderosae* (*monticolae*) Hopk., and 0.63 mg/kg for *Scolytus ventralis* Lec. In this series of tests, endrin and dieldrin were somewhat more toxic and DDT much less toxic to *D. brevicornis* Lec. In more recent tests (Lyon

1971), lindane had an LD₅₀ of 0.32 mg/kg for *Ips paraconfusus* Lanier. Several materials, including Zectran, Dichlorovos, Enosulfan, and malathion were as toxic or more toxic than lindane when applied topically to *D. brevicornis*. Lindane is equally effective against other insects. Reported LD₅₀ values for various species are in the range of 2 to 5 mg/kg (O'Brien 1967).

Nontarget toxicity--The contact toxicity to rats (LD₅₀) is reported to be 900 to 1000 mg/kg, and the acute oral LD₅₀ is 88 to 91 mg/kg. Rats fed on a diet containing 10 p/m for 12 months suffered no ill effects (Martin 1968). The acute oral LD₅₀ for ducks is reported to be greater than 2000 mg/kg (Tucker and Crabtree 1970), suggesting that lindane is less toxic to birds than mammals.

Upon entrance into an animal body, lindane is distributed to various organs and tissues. It has been found in the blood, liver, spleen, adrenal glands, muscle tissues, brain, kidneys, and fat of treated animals. Storage is greatest in fat, although it is also deposited in the liver and kidneys. Lindane is deposited in tissue lipids at the same concentration as contained in the diet (Counc. Pharm. Chem. AMA 1951).

Menzie (1966) summarizes the available data (much of it in foreign languages) on the metabolism of lindane in animals. There is substantial agreement that lindane, given by several routes to various experimental animals, is broken down to trichlorophenols or 1,2,4-trichlorobenzene and excreted mainly in the urine. These compounds are nontoxic and water soluble. In several studies, experimental animals metabolized and excreted doses as high as 100 mg/kg in 2 to 3 weeks. Parke (1968) quotes a metabolism rate of 5 to 10 percent of the administered dose of lindane per day in rats.

Grover and Sims (1965) investigated the metabolism of lindane by administering 40-mg/kg doses of lindane to rats by intraperitoneal injection every other day. They found the lindane was metabolized to 2,3,5- and 2,4,5-trichlorophenol, which were excreted in the urine.

Because of its minimal storage in animal bodies and rapid elimination, lindane has not caused serious chronic toxicity problems in animals exposed to concentrations used in pest control operations. Rats fed on a diet containing 10 p/m for a year suffered no ill effects (Martin 1968). However, the Council on Pharmacy and Chemistry, AMA (1951) reports liver degeneration and nutritional disturbances in dogs exposed over a long period of time.

Gakstatter and Weiss (1967) exposed four species of fish to water containing 0.03 p/m lindane. Two days after termination of exposure, the fish had eliminated 90 percent of the lindane they had accumulated.

According to Sternberg and Kearns (1956), houseflies receiving sublethal doses of lindane metabolize it to pentachlorocyclohexene. The concentration of pentachlorocyclohexene rises for 2 hours after treatment, then levels off, indicating that it is being further metabolized. Grover and Sims (1965) suggest that lindane metabolism proceeds via pentachlorocyclohex-1-ene to trichlorophenols as it does in rats.

Lindane is also metabolized by at least two common bacteria (Allan 1955). The bacteria convert lindane to benzene, monochlorobenzene, and 1,2,3,5-tetrachlorobenzene.

Lindane is considered to be nonphytotoxic at insecticidal dose levels, but high concentrations interfere with germination, suppress growth, and reduce yields (Thomson 1967).

Persistence and stability--Lindane is much more stable in soil than in living animals. In a study in Wisconsin, Lichtenstein and Shultz (1959) applied lindane to a sandy loam soil at a rate of 100 pounds per acre! Three and one-half years later, they were able to recover 23.2 percent of the originally applied material. However, a bioassay showed only 10.7 percent of the original level of toxicity. They concluded that half of the material recovered was actually an inactive breakdown product of lindane. Lindane applied to ponderosa pine bark as a 2 percent oil solution remained effective against two species of *Dendroctonus* beetles for 3 years (Smith 1970), indicating the rate of breakdown and/or loss of lindane from bark is probably no faster than that reported for lindane in soil.

Handling safety and convenience--Lindane is a comparatively safe insecticide to handle. The Council on Pharmacy and Chemistry, AMA (1951) reports an estimated acute oral toxicity of 150 mg/kg for adult humans, (about 7½ grams for an average adult) based on results of attempted suicides and accidental ingestion. There is evidence that inhalation of lindane vapors from thermal vapor dispensers has caused a fatal blood disorder, aplastic anemia (Loge 1965). Workers in mixing and formulating operations where they were exposed to lindane dust suffered dermatitis and irritation of the upper respiratory tract, eyes, and skin (Counc. Pharm. Chem., AMA 1951). There have been no reported problems with lindane as used in forestry. Normal safety procedures have been effective in protecting personnel applying lindane.

Lindane has a higher vapor pressure than the other chlorinated hydrocarbons, but normally it must be heated to release insecticidal concentrations in large volumes, as in a room. It is almost odorless.

Lindane is stable to air, light, heat, and carbon dioxide. It is not attacked by strong acids but is dehydrochlorinated by alkali. It is not corrosive to common packaging materials nor affected by them. Thus it can be stored for long periods in uncoated metal containers in ordinary warehouse facilities. It is soluble in water to the extent of 10 p/m, and readily soluble in acetone, aromatic, and chlorinated hydrocarbons (Martin 1968). It is easily formulated as oil-based solutions, water emulsions, and dusts.

Lindane is thus an effective insecticide against bark beetles, killing our common species at dose levels of 0.32 to 7.3 mg/kg. It is equally toxic to nontarget insects, but much less toxic to nontarget mammals, birds, and plants. It is nonpersistent *in vivo*. Insects, mammals, fish, and bacteria rapidly metabolize it to nontoxic products which are quickly excreted. It accumulates in fat at the level contained in the diet. The low accumulation potential, together with its rapid breakdown rate, would largely prevent it from moving in food chains or accumulating in top predators.

It is moderately stable in soil and bark but apparently resistant to removal from the site of application by physical factors. It is not especially hazardous or unpleasant to handle as used in bark beetle control, but may be a health hazard when dispensed by thermal vaporizers. Excellent solubility and stability characteristics permit easy formulation and storage.

As compared with the ideal insecticide for bark beetle control, lindane has two main flaws. It is not as selective as might be desired, killing other insects as readily as bark beetles; and it is more persistent in bark and soil than is strictly necessary. We partly compensate for the lack of selectivity by restricting application to portions of the bark of selected, individual trees. Nevertheless, the broad-spectrum activity of lindane means that parasites and predators in those trees are lost.

The quantity of lindane persisting in bark could easily be reduced. The data showing that lindane treatments are still effective 3 years after application strongly suggest that we are supplying more lindane than is necessary to control beetles emerging from infested logs. What is needed is perhaps 6 months of effectiveness, rather than 3 years. Surely some more dilute solution of lindane can be found to have that period of effectiveness and save money as well.

Lindane is probably not the best insecticide presently available for bark beetles. Several other insecticides, among them malathion, are more toxic to bark beetles than lindane (Lyon 1971). However, I feel that we should not immediately substitute some other insecticide. Candidate replacements for lindane must first be field-tested. They should also be judged by the standard of the ideal insecticide. Lindane, though certainly not ideal, has some excellent properties of safety and biodegradability. Any material considered to replace it should possess these properties and, in addition, have fewer flaws. There is little point in trading one set of undesirable properties for another.

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Lindane Residues in the Environment

George T. Ferrell

Abstract --Lindane residues have been found at low levels in a variety of crops, animals, soils, and waters in the United States, indicating that widespread contamination exists. Lethal or sublethal effects on wildlife have not been found and magnification in food chains has been minimal, probably because of lindane's relatively rapid breakdown and low tendency to be stored in fat in living organisms. Lindane is persistent in certain soils, however, and is relatively volatile and water-soluble. Heavy applications on a broad scale could result in severe environmental contamination.

Lindane (gamma benzene hexachloride) is a broad-spectrum insecticide used internationally to protect apples and other fruits; beans, peas, cole crops, cucurbits, tomatoes, and other vegetables; rice and other cereals; seeds; livestock; households; and logs and lumber. Lindane production in the United States is substantial; it amounted to 7.7, 3.4, and 1.8 million pounds in 1961, 1962, and 1963, respectively (U. S. Dep. Health, Educ. and Welfare 1969). Large amounts are also produced in Europe (statistics unavailable). Primary dependence is placed on benzene hexachloride for insect control on fruit in Japan, India, and Algeria; rice in Asia and South America; cereals in India, United Kingdom, Mexico, Africa, and Turkey; vegetables in India, Japan, Mexico, and Spain; sugar beets in Italy and Turkey; sugarcane in Mexico, Australia, India, and Brazil; and oil seeds (i.e., sesame, soybeans) in India and Japan.

The distribution, concentration, and sublethal effects of persistent organochlorine pesticides in global air, soil, water, and life is of widespread concern. These residues are difficult to identify by gas-liquid chromatography (GLC), the usual method, as many pollutants (including nonpesticides like polychlorinated biphenyls, used as plasticisers) have similar retention times. Confirmation of lindane's identity by mass spectrometry is desirable but may not have been a part of all studies cited in this paper. A degree of skepticism regarding these residue reports is therefore justified. This paper is a brief review of present knowledge of the fate and effects of lindane residues.

AIR

The presence of pesticides in air is a function of their chemical nature, their physical state, the method of application used, and the atmospheric conditions during and after application. Pesticides may be lost from air by gravitational fallout, rain washout, and degradation by sunlight and chemical reactions.

Lindane in small droplets or thin films is about four times more volatile than DDT (Qurashi 1970); its vapor pressure is about 60 times that of DDT (Frear 1955). Organochlorine pesticides have had wide distribution in the global air system and have been detected even in the mid-Atlantic air (Risebrough and others 1968). Rainwater collected over a 12-month period at seven widely distributed sites in England always contained traces of lindane (Tarrant and Tatton 1968), as did 34 of 90 rainwater samples from three sites in Ohio (Cohen and Pinkerton 1966). The persistence of lindane in the atmosphere is not known, but small particles (theoretically including lindane as small crystals adhering to dust particles or water droplets) spend about 30 days in the atmosphere before being washed out by rain, whereas vapors generally stay aloft about 2 to 4 months (Newell 1971).

WATER

Lindane's water solubility is about 10 p/m, or about 50,000 times that of DDT (Frear 1955). Pesticide monitoring of 20 rivers in western North America, during 1965-66 (Brown and Niskiocka 1967), showed lindane to be the most

frequently encountered pesticide (46 of 165 positive samples) but in 1967-68 it was much less frequently encountered and spotty in distribution (Manigold and Schulze 1969), occurring in 10 samples in four rivers. Data on contamination of ground water were not available. The average concentration of lindane at the intakes from Lake Michigan to two Chicago filtration plants in April 1969 was 0.015 p/b, while DDT averaged 0.42 p/b (U. S. Dep. Health, Educ. and Welfare 1969). A sampling of many California bays and estuaries for organochlorines only infrequently found lindane contamination (Modin 1969). Data on the persistence of lindane in water were not found.

SOIL

The persistence of residues of a given pesticide in soil is a function of soil variables such as texture, organic content, pH, and chemical composition; climatic factors such as rainfall and temperature; and characteristics of the pesticide such as thermostability, solubility, affinity for soil constituents, and biodegradability. In some soils lindane can persist for many years. Annual disappearance rates have varied from 16 percent (MacPhee and MacEachern 1960) to 36 percent (loam) (Allen and others 1954). Assuming a 20 percent annual disappearance rate as average, the "half life" in soil would be 3 years. About 3 percent of the lindane originally applied would still be present 15 years after application. After application of lindane three to five times per year for 15 years (1953-68) at the rate of 1.5 lb/acre/yr to a light, sandy soil, the lindane content was about 1.8 lb/acre (Voerman and Besemer 1970). Similar applications of DDT resulted in 4.6 lb/acre after 15 years. Concentrations of both pesticides were believed to have reached a steady state. Evidence of biodegradation of lindane in submerged agricultural soils (rice paddies) was found. Less than 10 percent of applied lindane was left after 90 days in unsterilized soils, whereas residues were much higher when the soil was sterilized (Raghu and MacRae 1966). Because of instability under high pH conditions, lindane would likely break down more rapidly in alkaline than acidic soils. Codistillation of lindane and water vapor from water surfaces and moist soil undoubtedly occurs, but reports of determinations of this were not found in the literature.

WILDLIFE

The persistence of pesticide residues in living tissues is a function of the rate of uptake, as determined by food habits, environmental contamination, and tissue storage; and the rate of loss, as determined by the rate of metabolic breakdown and elimination in urine and feces.

Residues of lindane in wildlife have been widely found, especially in Europe. Hawks found dead or dying in the Netherlands had residues of a number of organochlorines; lindane concentrations were 3.2 to 17.7 p/m (brain) and 89.3 p/m (mesenteric fat) (Koeman and van Genderen 1966). The blubber of a gray whale washed up on a California beach contained 0.2 p/m lindane, 0.2 p/m DDT, and 0.5 p/m DDE (West 1964), indicating river or air transport to marine environments. A survey of Irish wildlife (Eades 1966), including eggs and a variety of adult tissues of land and sea birds, salmon and trout, and one mammal (foxhound), found a variety of organochlorine residues in all samples. Lindane was present in small amounts (0.025 to 0.67 p/m) in all birds examined. The foxhound contained 0.32 to 0.72 p/m; the fish, 0.1 to 0.30 p/m; and all eggs examined had trace amounts of lindane (0.004 to 0.03 p/m). The contamination of sea birds again indicated river or air transport of lindane to the sea.

Nationwide summer, fall, and winter collections of U.S. starlings from 106 sites found lindane residues (0.005 to 1.250 p/m) occurring in summer at 4 sites, in fall at 17 sites, and in winter at 84 sites (Martin 1969). The geographic distribution of lindane residues was widespread but showed little meaningful pattern. Lindane was usually found in birds with the highest fat content. Winter deposition of fat combined with a seasonal shift to a more herbivorous diet may explain the greater lindane residues at that season. A nationwide sampling of mallard and black duck wings found lindane residues at trace level (< 0.05 p/m) in only Washington and Michigan, where lindane had been used for aphid control in apple and pear orchards (Heath 1969).

A survey of herbivorous and carnivorous fishes collected at 50 locations throughout the continental United States in 1967-68 found DDT residues (often above 1 p/m) in all but six of 590 fish samples (five of those lacking DDT were collected at one station in Alaska) (Henderson and others 1969). Lindane was found in 16 percent of the samples, usually at concentrations of less than 0.1 p/m. Lindane was not found consistently at any sampling station over time, as were DDT and dieldrin.

In spite of very limited usage of lindane in South Dakota, a survey of tissues from various big game populations throughout the State found lindane residues in 15 percent of these mammals in average concentrations of 0.04 p/m (Greenwood and others 1967).

Nearly all (40 of 43 samples) adult tissues and eggs of chinstrap penguins, brown skuas, and blue-eyed shags, and livers of a fish (*Nototheria* sp.) collected on Signy Island near Antarctica

contained lindane at 0.001 to 0.006 p/m, and other organochlorine residues at slightly higher levels (Tatton and Ruzicka 1967). Planktonic krill (*Euphausia* spp.), the major food of the penguins, also contained traces of these residues. The collection site is located more than 1000 km from South America. Prevailing wind and ocean currents are from New Zealand, 15,000 km distant. Contamination of Antarctic wildlife far from the nearest regions of application indicates the global scope of the transport of lindane and other organochlorine residues.

Although lindane residues are widespread in wildlife, there is presently no evidence suggesting ill effects. Lindane is not concentrated in living organisms to the extent that DDT and dieldrin are. Laboratory exposure of oysters (filter feeders) to water containing organochlorines at 0.001 to 0.05 p/m for 10 days resulted in magnifications in oyster tissues of 17,000X for heptachlor, 15,000X for DDT, and 60X for lindane (Wilson 1966).

Intensive sampling of various components of the aquatic ecosystem in Lake Poinsett in South Dakota gave results (table 1) indicating both lindane and DDT were concentrated to a greater extent at higher trophic levels in the food chain, although the DDT accumulations in aquatic insects and fish were 333 and 12 times, respectively, greater than those for lindane. When chickens were fed a diet containing 10 to 15 p/m of various organochlorines for 5 days, residues were detectable in body fat and egg yolk for 10 weeks for lindane, 17 weeks for DDT, and 26 weeks for dieldrin, heptachlor epoxide, and DDE (Stadelman and others 1965).

Table 1--Distribution of residues and concentration factors (CF), Lake Poinsett, S.D.

Component	Lindane		DDT	
	P/m	CF	P/m	CF
Water	8×10^{-5}	1	8×10^{-5}	1
Bottom sediment	2×10^{-4}	6.6	22×10^{-4}	30
Plankton	2×10^{-4}	6.6	5×10^{-3}	62
Crayfish	1×10^{-3}	33	2×10^{-3}	25
Aquatic insects	1×10^{-3}	33	.919	11,000
Fish	3×10^{-3}	100	.100	1,200

Source: Hannon and others 1970

Although lindane residues render food repellent to many species, pheasants could be conditioned to accept a lindane-contaminated diet by gradually increasing the concentration. At an average daily dietary intake of 87 p/m, reproductive effects were noted. The dosed birds exhibited a slight decrease in the number of eggs produced, and peak egg production was delayed (Ash and Taylor 1964). Lindane concentrations in the eggs of the experimental birds were 3.4 to 12.6 p/m and averaged 5 p/m in wild birds. Upset of avian reproduction (delayed egg production or thinned eggshells) resulting from DDT residues has been found in a number of species and is thought to be contributing to rapid declines of certain raptors (Peakall 1970). Lindane has been found to stimulate (induce) hepatic microsomal enzymes which enhance the metabolism and excretion of steroid hormones (Koransky and Portig 1962). Such effects are also produced by DDT and some other organochlorine pesticides. The influence of this upon avian reproduction is under current investigation.

Experimental diets containing lindane at 30 mg/kg of body weight/day for 30 days (30-day, empirical, minimum lethal dose, or 30-day EMLD) resulted in one or two of six mallards dying, but more than 2000 mg/kg/day were required to kill three of six ducks (LD₅₀) within 14 days (Tucker and Crabtree 1970). An index of the cumulative toxicity effect of lindane may be calculated: LD₅₀/30-day EMLD - 2000/30 = 67. The authors considered this effect highly cumulative, even for an organochlorine. Similar methods and calculations yielded indexes of 76 for dieldrin; 44.8, DDT; 45, endrin; and 104, aldrin. Some of these indexes are higher than that of lindane, largely because although they have greater acute toxicity (lower LD₅₀), they also have higher cumulative action (lower EMLD), than lindane.

It is well known that broad-spectrum pesticides such as lindane disrupt the trophic relationships within ecosystems by reducing the abundance of nontarget insects, thus reducing the food supply for insectivores. Insectan predators and parasites of pest insects are also destroyed, resulting in a disruption of biological control of pest insects. Experimental concentrations of some organochlorine insecticides in ambient water can reduce the photosynthetic productivity of plankton, which lies at the base of all food chains in these environments. The ecological significance of this effect is doubtful, however, as the chlorinated hydrocarbons in natural aquatic environments have never been observed to reach the experimental concentrations. Controlled, 4-hour exposure of phytoplankton to 1 p/m of aldrin, chlordane, DDT, dieldrin, heptachlor, methoxychlor, and toxaphene reduced productivity by 70 to 94 percent, whereas endrin, lindane, and

mirex caused a 28 to 46 percent reduction (Butler 1963).

Under conditions of heavy use of lindane, the potential for damage to wildlife exists. At rates and amounts presently applied, however, no deleterious effects attributable to lindane have as yet been reported. French workers were unable to find noteworthy changes in the bird populations of a 40-hectare pasture and woodland treated in early spring with BHC containing 10 percent lindane at 50 to 70 lb/acre (Giban and Aubry 1956). Nest boxes for tits had been installed in the woodland the preceding winter. Reproduction, development of young, and nesting mortality were apparently normal compared to control nest boxes.

In Russia, aerial dusting of field margins and forest strips for protection of crops with 12 percent BHC did not appear to have negative influence on the avifauna (Kadochnikov 1951).

CONCLUSIONS

Lindane's relatively low acute toxicity makes it unlikely that wild birds or mammals would suffer mortality from levels now used in agriculture and forestry. Lindane's relatively rapid breakdown in living tissues into readily excreted products of low toxicity and relatively low tendency to be stored in fat and other tissues make magnification in food chains minimal at the levels used in the United States. However, lindane is persistent in certain soils and is relatively volatile and water soluble. If applied frequently in large amounts, it could result in serious environmental contamination. Of 29 articles in the *Pesticides Monitoring Journal* for the period 1967-70 reporting residues of organochlorine pesticides, 25 recorded lindane residues. Although often at low levels, these residues were encountered in a wide variety of crops, animals, soils, and water, indicating widespread contamination.

Since the 1940's, worldwide applications of DDT have exceeded those of lindane by a thousandfold. Greatly increased use of lindane, in amounts approximating the quantities of DDT used in the past, would likely damage the primary productivity of aquatic environments and cause increased environmental contamination, which could lead to reproductive upsets in birds at the top ends of food chains.

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Effectiveness of Lindane Against Bark Beetles and Wood Borers

Richard H. Smith

Abstract--There is strong evidence in the literature that lindane is effective as a remedial and preventive treatment against many species of bark beetles: western pine, mountain pine, black turpentine, southern pine, Douglas-fir, and Engelmann spruce beetles, and several species of *Ips* and *Scolytus*. Hosts include slash, loblolly, ponderosa, sugar, lodgepole, white, and red pines, and Douglas-fir, Engelmann spruce, and elm. Formulations range from 0.25 to 3.0 percent as oil solution or aqueous emulsion; tested dosages range from about 50 to 200 ft² of bark per gallon. Insect population reductions for the materials treated range from 80 to 100 percent. Prophylactic action persists for up to 3 years. Lindane is also effective against cerambycid, buprestid, and ambrosia beetles, as well as against powder-post beetles, old-house borers, and subterranean and nonsubterranean termites; effects generally persist against this latter group for 3 to 7 years.

The field effectiveness of lindane in controlling bark beetles, borers, and other wood-feeding insects has been widely studied. This paper, though not an exhaustive review, covers tests involving a wide variety of insects, hosts, and formulations over a long period of time, in widely separated areas. In every use, the insecticide was closely restricted to narrowly defined targets such as individual trees, logs, and wood products. There were no broadcast applications.

Tests for each species or group of bark beetles can be divided into remedial and preventive types. In remedial tests, the insecticide was applied to infested material and an assessment of results was made from failure to emerge and/or from reduced longevity or capability, such as boring and oviposition, after emergence. In preventive tests the insecticide was applied to uninfested trees or logs which were then exposed to attack after varying periods of time; effectiveness was measured by the absence of attacks. Dosage was expressed in various ways but most often as gallons per square foot or as application to the point of "wetness" or "runoff"; these last two measures can be converted to 1 gallon for approximately 100 and 50 ft² of bark surface respectively. Diesel oil was the usual carrier for oil solutions; aqueous emulsion was always the form of emulsion used. Much of the early

work was done with the gamma isomer of benzene hexachloride, BHC; in these tests some of the other isomers were present. More recent tests used lindane, the pure gamma isomer. However, lindane and BHC produce essentially the same results.

Some of the early testing of lindane with bark beetles utilized a topical application procedure; much of that work has been reviewed by Lyon (1965). In his studies with western pine beetle, mountain pine beetle, fir engraver, and *Ips* engraver, he found lindane often superior to most other chlorinated hydrocarbons. He used the term "uncommonly toxic" to sum up his findings.

The review of test results is arranged by insect species or commonly associated groups of insects. Under each insect, or group, the results are reported as either remedial tests or preventive tests as defined above. Dosage, unless otherwise specified, is for square feet of bark. Brood reduction for remedial use is measured by failure to emerge plus mortality during the first 24 to 72 hours after emergence. Effectiveness for preventive use is measured by absence of attacks when compared with untreated material.

Western Pine Beetle
(*Dendroctonus brevicornis* Lec.)

Field tests were all made on ponderosa pine (*Pinus ponderosa* Laws.) in California.

Remedial

1. 92 percent brood reduction resulted from 1.5 percent lindane in oil, presumably at 1 gal/100 ft²; spray was applied just before the start of emergence (Lyon and Wickman 1960).

2. 87 to 99 percent brood reduction resulted from 1.5 percent lindane emulsion against overwintering brood. Spray was applied to wetness 1 to 5 months before emergence. Variation in percent reduction was largely attributable to time of application (Lyon and Swain 1968).

Preventive

1. 100 percent effectiveness was obtained for 12 months and 3 months with 2.5 percent lindane in oil and lindane emulsion, respectively, at 1 gal/50 ft² (Smith 1967).

2. 74 percent effectiveness was obtained for 7 months with 1.3 percent lindane emulsion applied to fire-damaged ponderosa pine; dosage not given. Reduction in subsequent tree mortality varied from 50 to 100 percent, depending on amount of fire damage^{1/}; that is, some of the more heavily fire-damaged trees which were sprayed died, but at a much reduced percentage.

3. 99 percent effectiveness was obtained for 36 months and 22 months by 2.0 percent lindane oil and emulsion, respectively, at 1 gal/50 ft² (Smith 1970).

Mountain Pine Beetle
(*D. ponderosae* Hopk.)

Field tests were made on both ponderosa and lodgepole pine (*P. contorta* Dougl.) in California and on ponderosa in Colorado.

Remedial

1. 90 percent of the brood was killed in lodgepole pine by 1.5 percent lindane in oil applied 1 to several weeks before emergence, presumably at 1 gal/100 ft². Although some trees were missed, the subsequent infestation was reduced to 25 percent of its former level

on an 85-acre plot (Wickman and Lyon 1962). [In an infestation of this type, it is assumed that the infestation level will be maintained if not treated (Evenden and Gibson 1940; Struble and Johnson 1955)].

2. 92 and 97 percent brood reduction resulted from 0.5 and 1.5 percent emulsion, respectively, applied to wetness about 2 months before emergence from ponderosa pines (Stevens and Mitchell 1970).

Preventive

1. 100 percent effectiveness resulted with 2.0 percent lindane oil solution for 36 months, and 91 percent with a 2.0 percent emulsion for 22 months on ponderosa pine at 1 gal/50 ft² (Smith 1970).

Black Turpentine Beetle
(*D. terebrans* [Oliv.])

Field tests were with slash pine (*P. elliotii* Engelm.) and loblolly pine (*P. taeda* L.) in Florida, Mississippi, and Louisiana.

Remedial

1. 82 to 89 percent brood reduction was obtained in slash pine stumps with 0.5 percent BHC in oil, and 59 to 68 percent with 0.5 percent BHC emulsion, when applied at $\frac{1}{2}$ gal/50 ft² several weeks before emergence.

2. Inconclusive results were obtained on loblolly pine in Louisiana when a 1.0 percent BHC oil solution was applied to runoff to 1-month-old stumps in a 2000-acre cutting area. Two-thirds of the area was treated; one-third was untreated (Kucera and others 1970).

Preventive

1. 100 and 98 percent effectiveness was obtained with 0.5 percent BHC in oil for 4 months and 7 months, respectively, on slash pine at 1 gal/50 ft². About 10 percent of untreated trees were attacked, and killed; no treated trees were attacked.

Preventive and Remedial

1. 90 percent effectiveness was obtained in reducing the incidence of attack on untreated, previously unattacked slash pine and

^{1/} Swain, Kenneth M. 1968. Protecting ponderosa pine from bark beetle attack by use of a lindane-water emulsion spray. Report on file, USDA Forest Serv., California Region (R-5), San Francisco. 13 p., illus.

^{2/} Smith, R. H. 1956. Studies of the black turpentine beetle (*Dendroctonus terebrans* [Oliv.]) in slash pine: 1952-1955. Final report on file U.S. Forest Serv., Southeastern Forest Exp. Stn., Asheville, N. C., 75 p., illus.

75 to 80 percent effectiveness in reducing subsequent tree mortality where trees were sprayed within 1 month after being attacked, with 1.0 percent BHC in oil at 1 gal/50 ft²; test was maintained over an 18-month period (Smith 1958).

Southern Pine Beetle
(*D. frontalis* Zimm.)

Remedial.

1. 97 percent brood reduction resulted from both 1.0 percent BHC emulsion and 0.5 percent BHC in oil applied to runoff to bark of loblolly pine 1 to 12 weeks before emergence in summer; 97 and 81 percent, respectively, with the oil and emulsion applied 12 to 16 weeks before emergence in winter (Bennett and Pickard 1966).

Engelmann Spruce Beetle
(*D. rufipennis* Kirby)

Remedial.

1. 93 percent reduction in subsequent attack capabilities was obtained with 0.5 percent BHC emulsion; dosage was not stated but was presumably between wetness and runoff. Effects were determined by individually caging green logs with sprayed and unsprayed Engelmann spruce (*Picea engelmannii* Parry) stumps in Colorado and measuring subsequent oviposition (Massey and Wygant 1954).

Douglas-Fir Beetle
(*D. pseudotsugae* Hopk.)

Preventive.

1. 100 percent effectiveness over a 20-week period was obtained with 200 mg/1 ft² of lindane in oil applied to fresh-cut Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) logs. As an emulsion or suspension, this same dosage was 100 percent effective for about 10 weeks and 99 percent for 20 weeks (Rudinsky and others 1960).

Ips Engraver Beetles
(*Ips* spp.)

Remedial.

1. 100 percent brood reduction of *Ips confusus* Lec., the five-spined California engraver, in ponderosa pine in California was obtained with 1.5 percent lindane in oil (Lyon and Wickman 1960).

2. 89 percent reduction in longevity of emerged *I. confusus* brood from ponderosa pine and 84 percent from sugar pine was obtained with 3.1 percent lindane in oil in California. In addition, there was 75 percent reduction in emergence from ponderosa pine and 85 percent from sugar pine (Stark and Borden 1965).

3. 98 to 99 percent reduction in emergence of *I. pini* from red pine in Canada was obtained by 0.5 percent emulsion sprayed to runoff 4 to 5 weeks before emergence (Thomas 1970).

Preventive on logs.

1. 99 percent effectiveness against *Ips* spp. was obtained for 4 weeks in Florida with 0.5 percent BHC emulsion at 0.4 gal/100 ft² of longleaf pine (*P. palustris* Mill.) and loblolly pine logs (Hetrick and Moses 1953).

2. 90 to 100 percent reduction in egg gallery length of *I. lecontei* Sw. was obtained in ponderosa pine in Arizona by 1 percent lindane emulsion, 85 percent reduction with 0.5 percent, and practically no reduction by 0.25 percent (Ostmark 1969).

3. 100 percent effectiveness was obtained against *I. pini* (Say) in red pine (*P. resinosa* Ait.) with a 0.5 percent lindane emulsion applied to runoff a week before emergence of brood in the area (Thomas 1970).

Scolytus Engraver Beetles
(*Scolytus* spp.)

Remedial.

1. 85 and 94 percent reduction in emergence of *S. multistriatus* Marsh. was obtained with 0.5 and 1.0 percent lindane emulsion, respectively; spray was applied to runoff to American elm (*Ulmus americana* L.) in Connecticut in early spring. A late spring test showed only 78 and 72 percent (Doane 1958b).

Preventive.

1. 96 and 84 percent reduction in the feeding activity associated with disease transmission at 4 and 13 weeks, respectively, was obtained against *S. multistriatus* with 1 percent lindane emulsion applied to runoff to American elm; 0.5 percent was ineffective (Doane 1958a).

Ambrosia Beetles

All tests were preventive on logs.

1. 60 to 100 percent effectiveness was obtained with 0.25 percent BHC oil on southern hardwoods. Insecticide was applied as an instant dip, which is comparable to runoff; *Xyleborus affinis* Eich. and *Platypus compositus* Say were the most common beetles (Kowal 1949).

2. Highly effective protection was obtained for 3 to 4 months with 0.5 percent BHC oil at 1 gal/100 ft² on southern hardwoods (Johnston 1952).

3. 95 to 100 percent protection was obtained with any concentration greater than 0.1 percent BHC of either oil or emulsion, dosage not given, on red and white pines (*P. strobus* L.) in Massachusetts. Sprays were applied in the spring and exposed to attack until autumn (Becker 1955).

4. 100 percent protection for 20 weeks was obtained with 200 mg/ft² of Douglas-fir bark, as an oil. As an emulsion or suspension, the same dosage was 100 percent effective at 8 to 10 weeks and 99+ percent at 20 weeks (Rudinsky and others 1960).

Borers

(Buprestidae and Cerambycidae)

Remedial.

1. 99 percent brood reduction of *Melanophila californica* Van Dyke was obtained with 1.5 percent lindane in oil applied to wetness to Jeffrey pine (*P. jeffreyi* Grev. & Balf.) from 1 to 6 months prior to emergence; lag time between treatment and emergence had no effect on results (Swain and Wickman 1967).

Preventive.

1. 99+ percent effectiveness was obtained against cerambycids for 4 weeks on cut logs of slash, loblolly, and longleaf pine with 0.5 percent BHC emulsion at 0.4 gal/100 ft² of bark (Hetrick and Moses 1953).

2. 100 percent effectiveness was obtained against cerambycids on logs of red and white pine with > 0.1 percent emulsion BHC; there was 95 percent effectiveness with 0.1 percent but a rapid dropoff with concentration below 0.1 percent; dosage not given. Spraying decks of logs was slightly less effective (Becker 1955).

3. 100 percent effectiveness against buprestids was obtained for 20 weeks with lindane in oil at 200 mg/ft² of cut logs of Douglas-fir (Rudinsky and others 1960).

Miscellaneous

Wood Feeders

In all tests except those for subterranean termites, in which soil treatments were used, lindane was applied as a preventive spray or dip to wood.

1. 100 percent effectiveness was obtained against a powder post beetle (*Lyctus planicollis* Lec.) for 3½ years--the length of the test--with a 0.5 percent BHC oil dip on seasoned oak and hickory; an emulsion was about equally effective when applied to seasoning wood (Johnston and others 1955).

2. 100 percent effectiveness was obtained against subterranean termites for 6 years with a 0.4 percent BHC oil applied at the rate of 2½ gal/10 ft³ of soil in Mississippi; 70 percent effectiveness was obtained at 9 years (Johnston 1958).

3. Lindane at 0.5 percent in oil as a brush or spray is recommended for prevention of old-house borer attacks (*Hylotrupes bajulus* L.) (McIntyre 1961).

4. BHC at 0.4 percent in oil is recommended for remedy of drywood termite infestations (Snyder 1950).

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Lindane: An Undesirable Approach to Bark Beetle Control

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Abstract--Bark beetles have been of concern to foresters for many years. Although much effort has been made, direct control of beetle populations has not been demonstrated. Lindane has been shown to be capable of efficiently killing beetles, but population control on an area-wide basis has never been shown. It is not economical compared to sanitation logging, and its side effects on the natural enemies of bark beetles are unknown. Direct control of bark beetles using lindane is potentially an ecologically unacceptable procedure. The most environmentally sound procedures for bark beetle control appear to be improved stand management and sanitation salvage-logging. The use of lindane should be discouraged.

Bark beetles are the most important forest insects in California and, no doubt, in the Western United States. Because these beetles mass attack and kill individual trees, their damage is readily seen, particularly when a large outbreak occurs. Examples are the outbreak of the western pine beetle, *Dendroctonus brevicomis*, in the Mother Lode region of California in the early 1960's and that of the spruce beetle, *D. rufipennis*, formerly known as *D. obesus*, in Colorado from 1941 to 1952. Bark beetles, unlike defoliators, for example, not only kill the tree but also introduce a blue stain fungus which stains the wood. This fungus does not affect the structural quality of the wood (Whiteside 1951), but the staining affects marketability and there may be some difficulty in painting the stained timber.

WESTERN PINE BEETLE

Concern for control of the western pine beetle has a long history (Miller and Keen 1960). Attempts have been made recently to study the population dynamics of the beetle and to correlate tree loss with beetle numbers (Stark 1966; Stark and Dahlsten 1970). Even though this insect has received much attention in the past, a satisfactory control for this beetle is still being sought by many forest entomologists. In California, for example, there is a large cooperative effort aimed at control by means of pheromones. The most commonly used strategy for direct control with most bark beetle species is with chemical insecticides; however, in California an indirect sanitation-salvage approach

has been used with *D. brevicomis* and *D. jeffreyi* in the east side pine type.

SANITATION-SALVAGE METHODS

Reduction of stand loss due to bark beetles has been demonstrated by application of the California Risk Rating System or sanitation-salvage logging (Keen 1943; Salman and Bongberg 1942). By critically analyzing individual trees and removing those trees likely to be attacked in these pine stands, bark beetles were reduced by 70 to 85 percent over a 10-year period (Whiteside 1951). The stand volume was reduced by 15 to 30 percent. This type of cutting can be done at costs only slightly higher than the usual utilization cutting. The technique is applicable only to California east-side Sierra forests, however.

The sanitation-salvage method was also applied to recreation areas in southern California (Hall 1958). Hall tested the sanitation-salvage method to reduce losses of ponderosa and Jeffrey pines to bark beetles, principally *D. brevicomis* and *D. jeffreyi*. However, the California flatheaded borer, *Melanophila californica*, was present in both ponderosa and Jeffrey pines, and the mountain pine beetle, *D. ponderosae*, in sugar and ponderosa pines. The most interesting aspect of Hall's work was the cost analysis. In 1950, 554 beetle-infested trees were cut and burned in a control attempt on 2600 acres, at a cost of \$11,380, or approximately \$20 per tree. There was not enough money available to treat the entire infested

area. (Even if the money were available, the likelihood of detecting every infested tree in an area is remote, although detection and accessibility are easier in recreational areas than in timber-producing areas.) In 1951, the infestation continued at a high level: 1100 trees were detected on 6000 acres. Apparently the previous year's control efforts had little or no effect. The cost in 1951 for felling and burning was about \$22,000. Hall suggested the sanitation-salvage method, and a project was initiated in October of 1953 that lasted 14 months. Approximately 5500 acres were treated. After the treatment, the Forest Service maintained a year-round maintenance control. Infested trees were logged, and trees in inaccessible areas were felled and treated with ethylene dibromide in oil.

A close analysis of the results of this project is quite startling. Losses for 2 years before the sanitation-salvage treatment amounted to more than 200 board feet per acre annually. Unfortunately, check areas were not used; but Hall felt that the annual loss in southern California could be assumed conservatively to be in the neighborhood of at least 150 board feet per acre. At this level, losses were reduced by 92 percent in the first and 90 percent the second year. A side benefit of the treatment was the system of roads built during the operation, which subsequently made possible the salvage of 84 percent (72) of the infested trees in the 1956 season. These infested trees were sold at a nominal stumpage. (Hall never states what *nominal stumpage* is!) A comment should be made here regarding the sale of beetle-killed timber. These trees should be as marketable and sell for the same stumpage as other trees of the same species. A comparative study of the value of the principal species at the time they were salvaged would be interesting, and also critical to the development of sound control practices.

During 1956, Hall reports, 14 infested trees that could not be logged were treated at a cost near \$280. This represents the total control cost on 5500 acres. This is cheap for a control project, and if credit is taken for the 72 trees that were logged, it cost the Government practically nothing. It appears that these results are at least as good as the results obtained in northeastern California by Salman and Bongberg (1942).

Direct control at \$20 per tree would have cost close to \$190,000. However, using an indirect method, sanitation-salvage, the Government actually made about \$50,000 from the sale of the harvested trees.

DIRECT CONTROL

Direct control of bark beetle populations has never been demonstrated. Although Whiteside

(1951) states that it is possible to effect drastic reductions in western pine beetle populations on a control area for one or more years, data to support this statement are lacking or marginal. On the other hand, he does mention the high cost and the temporary nature of the "control." Direct control in the past consisted of the fell-peel-burn method, and later a chemical, ethylene dibromide (EDB) was used. Lindane, a chlorinated hydrocarbon, has now replaced most other treatments. It was shown to be effective in killing western pine beetle and the California five-spined ips, *Ips paraconfusus* (Lyon and Wickman 1960). In this study, trees were felled and treated with a 1.5 percent lindane-diesel oil spray. Sprayed and unsprayed bolts were brought into the laboratory and put into cages with freshly cut material. This test showed that lindane, indeed, would kill bark beetles. However, by caging the treated logs it may be possible to increase insecticide efficacy, particularly if there is any fumigant action of lindane. Treatment costs were not included in this study, nor were the number or kind of associated organisms recorded. The authors admit that it would be precarious to extrapolate from limited laboratory observations that control was actually attained.

In another test of lindane, this time against *D. ponderosae* in lodgepole pine in a fairly isolated stand, Wickman and Lyon (1962) found they could kill beetles; but tree mortality after treatment left something to be desired. As with the western pine beetle, the effect of lindane on the beetles was tested by caging treated and untreated bolts. They found that 90 percent of the beetles were killed; and, as in their previous study, no evaluation was made of mortality of associated organisms. The actual loss reduction in this isolated stand was 74 percent. The authors conclude that the insecticide was effective but that control was not achieved because of technical failures.

In attempting to find the source of these failures, the authors found that 7 percent of the infested trees were not spotted, but they also state that a 10-to-15 percent spotting error was not uncommon. It must be remembered that this was only an 85-acre isolated stand. In much larger areas with less experienced entomologists or no entomologists at all, the spotting error could be much, much higher.

The trees in this study were felled and jackstrawed, so that the undersides would be accessible to the spray. Normally, trees are treated, then rolled, so that the underside can be treated. This may explain why the control cost in their study was so low. Another technical failure in this project was spray coverage: it was found that 22 percent of the bark surface was left untreated. However, this was calculated from only one bolt with 4.5 ft² of

bark surface. A 5 to 10 percent coverage error for the project was estimated. Some beetles emerged through unsprayed bark, and others emerged through sprayed bark and survived. The 90 percent mortality figure reported would presumably be lower were it not for caging. Thus, a potential 12 to 27 percent of the population could escape treatment, and for most projects this is probably a low figure.

Wickman and Lyon (1962) state that the suppression achieved in their control operation compares favorably with results of other bark beetle control programs in California. Miller and Keen (1960) state that a 75 percent reduction in beetle-caused losses after spraying is frequently the maximum attained. The total cost for control of the Wickman and Lyon (1962) mountain pine beetle experiment was \$4.81 per tree, or \$1;202.65. The authors say that this is at least half as expensive as using penetrating oil sprays (such as ethylene dibromide). This cost figure is so much lower than cost figures listed by Hall (1958) and Swain (1968) that costs must have been determined in a different manner. However, Lyon (1959) claims that the tree need only be lightly coated with a residual-type spray like lindane, as compared to a penetrating oil spray, with which the bark surface must be soaked. Labor, transportation, and material costs are, therefore, much lower with lindane. Stevens and Mitchell (1970) recently corroborated this finding with a study on lindane to control the mountain pine beetle in the Rocky Mountains.

PREVENTIVE TREATMENT

Lyon (1959) suggested that residual-type sprays would have one prospective use that other types of sprays would not have, and that is that they would protect trees from attack. This concept has since received considerable attention, especially in the management of recreation areas.

In laboratory studies, Smith (1970) found that a 2 percent diesel oil solution of lindane applied to ponderosa pine bolts prevented western pine beetle and mountain pine beetle attacks for 3 years.

Swain (1968) tested the effectiveness of a 1.25 percent lindane-water emulsion as a prophylactic spray on standing trees in southern California. The area was ideal for this study, as many of the trees had been predisposed to bark beetle attack by a fire that had previously swept through the area. Only those trees that had the best chance for survival were treated and used as checks. One of the major problems was to get the spray high enough on the bole, but this was overcome by using a boom truck. The method would only be feasible, then, in areas of a relatively flat terrain. Swain

states that trees less than 50 feet in height could be reached with conventional ground equipment.

Only 9 of 100 sprayed trees (84 trees sprayed twice, 3 months apart) were killed by the western pine beetle, and none of the 9 killed trees was attacked on the sprayed portion of the bole (all attacks were above the sprayed portion). Swain concludes that one application prior to the time of overwintering brood emergence will give satisfactory protection from western pine beetle attack on the sprayed portion of the bole during the active bark beetle period (spring through fall). The trees were not attacked for a total of 7 months.

Swain set up cheesecloth catchment nets around the bases of five trees to catch dead or dying insects as they fell from the bole. The results were quite revealing as, of the 316 insects caught, 170 were *D. brevicornis* (53.7 percent), 21 were associated bark beetles (6.9 percent), and 125 were predators (110 *Enoclerus lecontei* and 15 *Temnochila chlorodia*) (39.4 percent). Incidentally, this is one of the few times that animals other than the target insect were counted. It is interesting to speculate what this type of predator mortality means, since both of these beetles are general predators of bark beetles and other wood-inhabiting insects.

The cost figures on the Swain (1968) project are much higher than those listed by Wickman and Lyon (1962). The total cost of Swain's treatment was \$3,208.00 calculated as \$17.16 per tree. This is misleading, however, as 84 of the original 103 trees were treated twice. The total cost of protecting these trees was more than \$31.15 per tree. Swain does state that there was no difference in protection afforded those trees treated twice over those treated once. The author goes on to point out that, in the same area in the preceding year, the mean cost of treating infested trees was \$25 per tree, and that the cost for prophylactic treatment was, therefore, less. Swain makes the statement that the land manager has the advantage of selecting the trees to be protected rather than spend money on treating trees which are already dead.

This last bit of reasoning must be examined. First of all, the land manager can presumably get three-fourths of the cost of a project paid by governmental agencies if his trees are infested, but payments are not made for the protection of trees. The land manager would, therefore, be ahead in paying, in fact, only \$5 to \$6 per tree for control rather than \$17 per tree for protection. Also, how often will trees need to be protected? Even using Smith's data (1970), indicating treatment every 3 years, costs would be unbearable. Secondly, why not

use a sanitation-salvage treatment, as shown by Hall (1958) to be an economical means of handling the bark beetle problem in southern California? Finally, what are the effects of the chemical on the environment? Swain's study (1968) showed nearly 40 percent of the insects killed to be natural enemies. The black-bellied clerid, *E. lecontei*, is known to be an important part of the natural enemy complement in the population dynamics of the western pine beetle (Stark and Dahlsten 1970). In the same study, it was shown that some 75 ± insects are associated with the western pine beetle. The long- and short-term consequences of using a chemical like lindane in the forest community, as well as on the cryptic community created by the beetle beneath the bark of the pine tree, must be carefully evaluated. To date, these effects are virtually unknown.

SPRUCE BEETLE

The spruce beetle, *Dendroctonus rufipennis*, formerly known as the Engelmann spruce beetle, *D. engelmanni* and *D. obesus*, presents another very different type of problem. This beetle destroyed 4.3 billion board feet of timber in western Colorado from 1939 to 1951 (Massey and Wygant 1954). The infestation was correlated with large blowdown that occurred in June of 1939. This outbreak is interesting from two standpoints: (1) the importance of the bark beetle in the succession of the Engelmann spruce forests and (2) the decision to embark on a large chemical control program near the end of the outbreak in 1950, 1951, and 1952.

Engelmann spruce beetle populations are favored by windfalls and overmaturity of spruce stands (Wygant and Nelson 1949). The windfall initiated this outbreak, and then the beetle populations continued in the overmature spruce, much of which may have blown down because of old age.

Engelmann spruce stands are largely two-storied, even-aged stands, the overstory in this outbreak being overmature and the understory being the suppressed reproduction. When the overstory is killed by the bark beetle, the understory is released. If this were allowed to continue through time, then Engelmann spruce would be maintained in the area largely through the periodic activity of the beetles. Ecologically this is a disclimax or disturbance climax because of the bark beetle. Wygant and Nelson (1949) report that previous outbreaks of this bark beetle occurred so long ago that their exact extent is not known. They do cite instances of several flareups but state that none of these earlier outbreaks approached the destruction of the 1939 outbreak, which continued for more than 10 years. It seems that the beetles play an important role in this forest type. More than likely, it is also clear that the blowdown trig-

gered the massive outbreak. In such an extensive outbreak, salvage would be impossible; but a different approach to the management of such a forest might clearly avert such a disaster. Sanitation cuts and harvest of the most overmature timber may become a necessity.

Much of the outbreak took place during World War II, so that no direct control procedures were attempted. Control was attempted from 1950 through 1952 with orthodichlorobenzene in No. 1 fuel oil--1 part by volume to 6 parts of oil (Massey and Wygant 1954; Massey and others 1953). It was later found that ethylene dibromide was just as effective and that workmen found it less disagreeable (Massey and others 1953). The orthodichlorobenzene-fuel oil solution was used to treat more than a million standing trees before EDB was substituted in 1952. No cost comparison was made between the two materials, nor were any figures given on the cost of the project. The main question is, of course, why was the decision made to control the beetles with chemicals? The effort necessary to get to infested trees and treat them could well have been used to salvage the logs. This is a much more economical approach, as I have pointed out earlier. Although both the materials used killed beetles, there was no evidence that populations were "controlled." In addition, control was not attempted until the tail end of the infestation.

CONCLUSIONS

Each bark beetle species in each situation is somewhat different. In some situations certain bark beetles play an important role in the ecosystem as does the spruce beetle. Where bark beetles are pests, it is clear from much of the literature that improved forest management practices are the key to the solution of the problem (Hopping 1921; Whiteside 1951; Wygant and Nelson 1949). There is no evidence that chemicals (orthodichlorobenzene, EDB, or lindane) have ever controlled a bark beetle population in the true sense of the word. These chemicals do kill beetles readily, and one worker, Swain (1968), demonstrated an effect on natural enemies. Two failures, both with lindane, have been recorded: one with the mountain pine beetle (Wickman and Lyon 1962) and another with the black turpentine beetle, *D. terebrans* (Kucera and others 1970). The study on *D. terebrans* showed that lindane reduced attacks, but did not reduce tree mortality. Two areas in California where control has been attempted are chronically infested with western pine beetle: in Blodgett Experimental Forest no apparent good was achieved, and in the area around Bass Lake, south of Yosemite National Park, chemical control activity has not achieved the desired end after several continuous years of treatment.

Cost figures given for lindane are so variable that comparison is virtually impossible. Jackson (1960) gives a cost of 48 to 60 cents per treated top for logging slash in a small logging unit. Osburn (1962) quotes a figure of \$2.48 per tree for falling, lopping some branches, and treating for trees above 7 inches d.b.h. Smaller trees were sprayed standing. Costs as high as \$25 per tree were reported by Swain (1968).

Cancellation of registration of lindane has been under consideration by the Federal Pesticide Regulation Division because this insecticide is a persistent chlorinated hydrocarbon. The question is: Of what use is lindane to the forest manager? Private forest industries in California do not use lindane for killing bark beetles, to my knowledge. Cost is apparently a deterrent factor. In the black turpentine beetle study, for example, a volume of 375 million board feet of saw-timber would have to be threatened in order for an annual expenditure of \$17,000 to be justified (Kucera and others, 1970). Control of beetle populations has not been demonstrated, and there are other alternatives available. Further, the use of persistent insecticides is questionable on the basis of side effects on nontarget organisms alone. There are no studies to show that lindane is not a hazardous material in this respect.

In my opinion, the California Forest Pest Control Action Council has *not* properly weighed the evidence of past research on forest pest problems. An example of this is the manner in which the direct control programs have been conducted. Person (1940) found that 40 to 90 percent of the bark beetle predator, *Enoclerus lecontei*, moved to the base of the tree and the surrounding duff prior to pupation. Berryman (1967) corroborated this work in his studies of predation on the western pine beetle. As long ago as 1927, it was recommended that stumps and surrounding litter not be burned during fell-peel-burn control of bark beetles (Miller and Keen 1960). Also, it has been suggested that trees be "high-stumped" to preserve these predators (Berryman 1967). Earlier studies had also shown that certain trees had high numbers of parasites, and it was suggested that these trees be spared to serve as a reservoir of natural enemies during control operations (DeLeon 1935). These recommendations were ignored, for the most part, until 1965, when the Council recommended that stumps not be sprayed except where *D. valens* is a problem. There was no mention of sampling for parasites or of "high-stumping," and it has never been demonstrated that *D. valens* is a pest.

In these times of increasing environmental deterioration, alternatives must be sought that are least disruptive to the delicate fiber of nature. Forest management solutions to bark

beetle control appear to be an avenue that should be given increasing attention. In a recent paper, Roe and Amman (1970) state that more effective mountain pine beetle control must consider such alternatives as type conversion, shorter rotations, mixing species, and the development of better size and age class distributions. This is ecological thinking, and the route that all insect control must follow in the future.

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Lindane Registration Should Not Be Retained

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Abstract--The registration of lindane should not be retained for the direct control of bark beetles because of potential adverse side effects. Lindane is a broad spectrum insecticide killing both beneficial and other non-target organisms. The efficacy of lindane has not been demonstrated for area-wide population suppression and furthermore, the strategy of using lindane in direct control of bark beetles could not be justified economically if it were effective. Silvicultural treatments aimed toward suppressing bark beetles provide more effective, economical, and lasting protection for forests than does direct control, whether by salvage or lindane spraying. The economic impact of bark beetles in California commercial forests is questioned.

Lindane has been shown to be an effective insecticide in a number of studies. Cost and ease of application certainly made it more desirable than previously used methods, such as treatment with ethylene dibromide and fell-peel-and-burn techniques. Effectiveness as an insect killer and suitability for control of a certain insect species population are two very different issues, however. It is our contention that control of bark beetle populations with lindane has never been demonstrated adequately. Public agencies, then, should not recommend control procedures until they have been proven effective. This is particularly true in these times of concern for the quality of the environment. It is especially unwise to recommend use of a chlorinated hydrocarbon until it has been shown to be absolutely safe.

The side effects of lindane are not known. Possibly, use of this chemical for bark beetle control may lead to the resurgence of the target species or create other insect problems, such as epidemics of other wood-boring species, by indiscriminate killing of beneficial insects. Until further research is done to show environmental safety for lindane, it should not be used. Even if the direct control procedure is absolutely safe, it should be used only if it is effective in controlling the target insect.

The necessity of using lindane in forest protection is certainly open to question. Our forests were not eliminated before the discovery of lindane. It has been recommended for bark beetle control in California for *only* the last

11 years (Lyon 1959). It has been recommended *only* since 1968 for use against overwintering broods of the western pine beetle, *Dendroctonus brevicornis*, (Lyon and Swain 1968).

The question is one of properly evaluating direct control methods. Prophylactic treatments with lindane have been suggested as a major reason why this insecticide is essential for the protection and management of forest lands in California. Protecting trees with a chlorinated hydrocarbon is a questionable procedure, as it is only a stopgap measure and must be continually repeated. If direct control of bark beetles in infested trees is not *essential* to forest management, then perhaps lindane may not be *essential*. Hall and Pierce^{1/} state, "The main failings of Direct Control are: high cost of accomplishment, near impossibility of finding all the infested trees before the beetles escape, and the fact that the treatment does little to alter any of the basic conditions which encouraged the outbreak in the first place." Studies conducted to assess the effectiveness of bark beetle suppression show inconclusive results. Swain^{2/}, in the Bass Lake Study, found

^{1/} Hall, R. C., and Pierce, J. R. 1965. Sanitation treatment for insect control. U. S. Forest Service, California Region, San Francisco. 21 p.

^{2/} Swain, K. M. 1966. Analysis of the Bass Lake insect control project. U. S. Forest Service, California Region, San Francisco. 7 p.

that losses on the suppression area were actually greater than in the check plot during 2 of the 5 years studied (in another year, loss on the check plot was only 0.01 percent per board foot per acre greater). Hall and Pierce^{1/}, discussing the case history of the Ranger Peak-Figueroa Mountain Direct Control Units, Los Padres National Forest, indicate that although higher losses were found on the untreated Ranger Peak, "... the 5 percent loss at Figueroa Mountain, however, is 10 times greater than the 0.5 percent level considered acceptable. Direct control alone will not assure that the loss can be reduced to tolerable limits needed to perpetuate the forest." In spite of the "favorable" characteristics of lindane, the California Region, U. S. Forest Service, uses lindane in direct control methods only for temporary suppression, mostly in recreation areas.

In view of these failures of direct control, the sanitation salvage or "thinning" technique should be considered in some detail as an alternative. The concept is not new. Both Hopkins (1909) and Person (1928) noticed that certain trees seemed to be attacked more frequently than others. Salzman and Bongberg (1942) and Keen (1943) advanced the eastside Sierra California Risk Rating System. Hall (1958) applied the technique to southern California recreation areas, and Hall and Pierce^{1/} reviewed certain case histories which firmly support the effectiveness of this method. More recently, Hall and Davies^{3/} state "thinning is an effective management tool in reducing the mortality caused by the mountain pine beetle in overstocked young stands of ponderosa pine." Pierce^{4/} maintains that "silvicultural treatments aimed toward suppressing bark beetles provide more effective, economical, and lasting protection for the forest than does direct control by salvage logging or chemical spraying."

If the foregoing arguments by Hall and others are credible, then it follows that permanent reduction in bark beetle populations could be obtained in California through proper cultural or forest management practices. Sanitation-salvage or thinning technique is operable under a wide variety of forest conditions and, in fact, is the *only control means* that has proven effective. Research in utilizing cultural prac-

tices for the suppression of insect pests was, for the most part, discontinued with the advent of DDT. It was not until the now classical insecticidal malfunctions (that is, resistance, disruption of biological balances, and contamination of food chains) became problems that this line of research was re-emphasized. Today lindane appears on the agenda of forest practices with many of the same credentials that were attributed to DDT in 1945, in that it is claimed to be safe, effective, persistent, cheap, and easy to use.

The major area of U. S. Forest Service bark beetle lindane suppression efforts for the last 10 years has been southern California, where arbitrary values have been placed on individual trees because of high public use. In Barton Flats, San Bernardino National Forest, Hall and Pierce^{1/} made a risk assessment in 1953; and a sanitation-salvage program was carried out. The Ranger District followed this with a direct control suppression program for the next 8 years, during which time losses remained low. When tree loss accelerated in 1961, following a period of prolonged drought, a reassessment of Hall's plots confirmed that many trees had moved into higher risk categories. The District moved into a "symptom treatment" program using direct control; that is, treatment of beetle-killed trees rather than removing high-risk trees. Had the District continued to risk rate and to remove the high-risk trees on an annual basis along with or instead of the annual suppression program, perhaps the 1961 flareup would not have occurred.

The economic impact of bark beetles in California's commercial forest has to be questioned. The Forest Service has had trouble in marketing trees from stand improvement sales. This was especially evident at the McCloud Flats thinning sale in 1968, when stumpage bid prices topped at \$5.95/Mbd.ft. It appears that lumber companies are most interested in the large block, allowable-cut sales and can afford to wait for them. Much of the silvicultural suppression must be done by the "gypo," or small operator, unless the project is "greened up" with a large block sale of prime timber resulting in a major stand reduction. The marketing policy of the Forest Service, as the major forest landowner in California, influences price structure. In the past only large land areas providing large volumes per acre have been economical to harvest. It is logical to assume that this economic condition restricts the investment that the private landholder can afford in stand improvement at 1970 prices; for instance, chipping tops for *Ips* control is not a feasible practice, nor are thinnings to reduce hazard to bark beetle infestations. We feel that the agencies responsible for direct control of bark beetles should re-evaluate their efforts and take a fresh approach to the entire problem. These agencies should be

^{3/} Hall, R. C., and Davies, G. R. 1968. Mountain pine beetle epidemic at Joseph Creek Basin, Modoc National Forest. U. S. Forest Service, California Region, San Francisco. 22 p.

^{4/} Pierce, J. R. 1968. Western pine beetle infestation, McCloud Flat, California 1968, Shasta-Trinity National Forest. U. S. Forest Service, California Region, San Francisco. 5 p.

looking at causes and not at symptoms. Also, they should evaluate what control procedures are economically feasible and are environmentally safe, and not retain techniques merely because of tradition or ease of handling.

If bark beetles are the threat, as stated in the California Forest Pest Control Action Council's brief (1.2 billion bd. ft. lost annually in California), then perhaps U. S. Forest Service management policy could consider the area of market manipulation. A restriction of annual cuts would drive the price up, and a further restriction would be to make stand improvement cuts first. If the timber supply is so great that the timber industry in this State cannot afford to do anything but harvest the "cream," or if the bark beetle impact has been overstated, then perhaps lindane is not essential.

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Lindane: A Useful Approach to Bark Beetle Control^{1/}

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Abstract--There is no single method of bark beetle control that is usable and effective under all circumstances. Lindane is one of several tools for bark beetle suppression which may be used singly or in combination with others. It would be unwise to discontinue the use of lindane, and thereby reduce the number of control methods available, without strong justification or before a superior replacement can be found.

The resolution of the Insect Committee states that the brief to EPA in support of continued use of lindane for bark beetle control did not state any attribute of the lindane control program that could not be achieved by other methods now in use, and that there is no evidence that the lindane treatment is an effective method of tree mortality prevention.

It is true that the brief failed to make these points; however, it does not automatically follow that there are in fact other methods now in use that could be substituted for the use of lindane, or that lindane, when used to kill bark beetles, does not prevent tree mortality.

The attributes of lindane are such that *when* it is used, as it is in the overall bark beetle control program in California, there are no other methods or materials available that could be employed under similar conditions or circumstances. Mechanical or cultural suppression methods, such as peeling and burning and logging infested trees, are frequently suggested as alternatives to the use of lindane. Such methods are not necessarily alternatives, they are, in fact, only *other* methods. In bark beetle control, the circumstances under which suppression is to be done are considered, and the best method is selected which will accomplish the *best* job; it is not a matter of arbitrarily selecting one of a number of equally rated methods. For instance, if the circumstances (i.e., tree merchantability, accessibility, and economics) indicate that logging be used to suppress an infestation, then logging is recommended; if the falling and burning

method is practical (and it sometimes still is), then the falling and burning method is recommended. If the circumstances suggest that spraying with lindane is the only practical method, we recommend lindane. Under some circumstances a combination of mechanical, cultural, and chemical control methods may be recommended.

An example of this situation occurred near Lake Almanor on the Lassen National Forest in 1967. In some parts of the infested area it was practical to log the infested trees (cultural control). In other parts of the area, merchantable trees were logged whereas trees below merchantable size, cull logs, and tops were sprayed with lindane. On the islands and along the shore of Mountain Meadow Reservoir it was practical to pile and burn infested trees (mechanical control). The records of bark beetle control operations in California in recent years show that methods other than the use of lindane sprays are recommended most of the time. Only a small fraction of the trees infested by bark beetles were treated with lindane. These represented those instances when the use of lindane, instead of or in combination with other methods, could be justified on the basis of conditions existing at each place where it was recommended.

At present there are no methods or materials with all the attributes of lindane that could be used interchangeably with lindane. Only one other chemical, ethylene dibromide (EDB) is available to the Forest Service for suppressing bark beetles.

EDB is a pesticide which exhibits fumigating activity of rather short duration. For some uses this is a highly desirable trait, but almost always it is not a trait desirable in an insecticide for bark beetle control. Granted that in warm weather EDB applied to the bark of beetle-infested

^{1/} Edited for publication in this volume by the compiler, T. W. Koerber.

trees will kill the developing broods; however, EDB has limited effectiveness in cold weather and because of its short residual life may not render the uninfested portions of treated trees toxic to slash-breeding insects. Thus, on the basis of effectiveness of suppression, lindane almost always tends to rate higher than EDB.

When conditions are such that EDB could be effectively substituted for lindane, the cost of the treatment is higher than spraying with lindane. Furthermore, EDB is notorious for causing skin irritations on direct contact and lung irritations when fumes are inhaled.

Many different tests have demonstrated that lindane mixed with either oil or water to form a 1.5-percent spray solution and applied to the bark of trees harboring beetle broods will on the average cause better than 90 to 95 percent reduction in the surviving emerging beetle population (Lyon & Swain 1968; Teillon and others 1973). It is obvious that bark beetles, either alone or in conjunction with other agents, kill trees. In a given forested area within a given period of time, if all or nearly all of the trees harboring developing bark beetle broods can be located and properly treated with a 1.5-percent lindane spray, the potential beetle population (emerging brood) can be drastically reduced. It follows that in the short run annual tree mortality from bark beetle attack will be reduced (Swain 1963; Wickman & Lyon 1962).

It is agreed that the use of lindane does not provide permanent or even long-term protection of forests from bark beetle attack and that if the conditions which prompted the occurrence of the bark beetle outbreak are not favorably altered, bark-beetle-caused tree mortality should be expected to resume promptly and increase to a higher level. However, cultural

methods (that is, logging just the infested trees) and mechanical, biological, and alternate chemical methods have not been shown to be more effective under the same set of conditions.

On the basis of laboratory screening studies conducted by the Insecticide Evaluation Research Work Unit of the Pacific Southwest Forest and Range Experiment Station, it appears that at least three insecticides are potentially as effective or better than lindane for control of the western pine beetle. Laboratory testing of candidate insecticides should be continued, and field tests of promising compounds should be conducted as soon as practical. When an alternate insecticide which works as well as or better than lindane is registered for use, we will promptly suspend the use of lindane in favor of the alternate material.

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Lindane Registration Should Be Retained^{1/}

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Abstract--Lindane has been adequately field tested and found effective against bark beetles. However, incorrect operational procedures sometimes result in failure to obtain population suppression. Lindane is rapidly metabolized and excreted by birds, animals, and humans, and the rate of application prescribed for bark beetle control should have minimal, if any, side effects.

Recreational use of National Forest lands in California is the heaviest in the nation, accounting for over 27 percent of all visitor use in 1970. This valuable recreation and timber land must be given the highest degree of protection possible. A major pest problem is bark beetles. To deal with this problem the land manager has a number of tools, among them preventive measures, such as sanitation cutting (the harvesting of high risk trees susceptible to bark beetles), or silvicultural treatment (thinning, release, etc.) to improve stand health and vigor. However, when significant tree loss occurs, direct suppression methods may be recommended. This often involves removing the infested trees from the stand either by logging or fuelwood sales. Sometimes it is not feasible to remove all the infested trees. They may be in an inaccessible location or the amount of site disturbance necessary to remove trees may be unacceptable, as in a recreation area. Often some of the infested trees are unmerchantable under prevailing market conditions. When other methods are not feasible, the infested trees can be treated with an insecticide. Currently, lindane is the most effective registered insecticide.

OPERATIONAL CONSIDERATIONS

The effectiveness of lindane as an insecticide is well documented. In the literature, lindane recommendations are backed up by adequate field testing. It follows that if suppression is not effective in operational use, failure is not the fault of the insecticide, but rather is due to incorrect operational procedure. Any of the following factors could contribute to failure to attain adequate

suppression:

- Poor timing of spray application
- Poor spray coverage (bark not sprayed)
- Missing of infested trees by spotter
- Improper mixing of lindane
- Crystallization of lindane at freezing temperatures
- Application of insufficient spray
- Use of lindane concentrate too low in lindane content

Assuming that the operational procedures are correct, then some degree of control should be obtained. The most obvious error in control projects is spotting. Keen (1960) states that with a three-man crew, after the first of November, about 90 percent of the trees will be found if the work is carefully done. From cruises of 106 sections it has been determined that the standard deviation of marking for any one spotter is plus or minus 20 percent. This is supported by Wickman and Lyon (1962), who found 90 percent mountain pine beetle mortality attributed to lindane at Silver Lake, whereas only 74 percent actual control was achieved because of missed trees and inadequate spray coverage.

Swain^{2/} reports losses on two comparative stands, one treated and the other untreated. In 1961, the loss in the treated stand was 5.5 percent of the stand volume and in the untreated stand the loss was 6.2 percent of the stand volume. The following year the loss was 4.7 percent of the stand volume in the treated stand and jumped to 28.6 of the stand volume in the untreated stand. The losses in the treated

^{2/} Swain, Kenneth M. 1963. Analysis of the Figueroa Mountain-Ranger Peak insect outbreak. Report of file, Div. Timber Manage., California Region, U.S. Forest Serv., San Francisco, 8 p.

^{1/} Edited for publication in this volume by the compiler, T. W. Koerber.

stand were higher than the desired level; however, in the untreated stand the lack of control resulted in catastrophic losses.

Hubbell^{3/} reports on a bark beetle control project against the Jeffrey pine beetle and the California flatheaded borer. The project was in an urbanized recreation area. All trees six inches and over were checked for two years in treated and untreated areas. At the end of this period the number of infested trees in the untreated area had increased by 204 percent ± 95 , whereas the number of trees in the treated area had decreased by 44 percent ± 21 .

EFFECTS OF LINDANE ON BIRDS, ANIMALS, FISH AND HUMANS

A major concern in the use of organochlorine compounds, such as lindane, is the likelihood of transfer in the food chain through a phenomenon called biological magnification. Dr. Francis Gunther (chemist and toxicologist, University of California, Riverside, personal communication) stated that he knew of no instances where lindane went through biological magnification. Dr. Gunther, editor of the 1970 edition of Residue Reviews, is a renowned authority on insecticides. Macek (1970) states that lindane and methoxychlor would not be expected to be biologically magnified to any great degree.

Certainly, any insecticide if given in large enough dosages will eventually cause noticeable side-effects or even death to the test animal. At the dosage and rate of application prescribed for bark beetle control in California, however, lindane should cause minimal side-effects, if any. In early testing in California, the California State Department of Fish and Game monitored our use of lindane. The Department's conclusion was that using lindane, in accordance with recommendations made by the U.S. Forest Service, was not harmful to wildlife. However, avoidance of the use of lindane adjacent to streams was suggested.

Birds

In many tests, various birds have been fed a diet containing specific percentages of lindane. Rudd and Genelly (1956) report a 10 percent mortality of pheasants resulted from eating grain treated with 1 2/3 ounces of 75 percent lindane per 100 pounds over a 20-day period. Other investigators, however, were unable to detect noteworthy changes in the bird population of a 40-hectare pasture and woodland

treated with 10 percent BHC (10 percent gamma) at approximately 50-70 pounds per acre. This application is about twice that normally employed. In addition, considerable field observation and experimentation in Germany have led to essentially the same conclusion. The small amounts of BHC that a wild bird could ingest would be insufficient to cause harm, because of the rapid disintegration of BHC within the animal body.

Ash and Taylor (1965) fed pheasants on lindane treated seed. They conditioned birds to low concentrations in the diet to overcome the problem of unpalatability. Eggs analyzed contained 0.4 to 22.1 p/m. Hatching was not impaired. The residues in eggs remained constant on continued feeding and for 5 days thereafter, but then fell rapidly for 15 days. Within 9 days after ingestion ceased, 66 percent of the initial residue had been excreted.

Liska and others (1965) placed young turkeys on treated rangeland immediately after it had been treated. At the end of four weeks the birds had 2.1 p/m of lindane in their body fat. Those placed on the range a week later contained only 1 p/m and those another week later 0.7 p/m.

In summary, the National Academy of Sciences (1969) indicates that field applications of lindane have no toxic effect on birds.

Animals

Groups of 20 rats were maintained for two years on diets containing from 5 to 1600 p/m of the alpha, beta, and gamma isomers of BHC. Gamma BHC (lindane) had the lowest toxicity, beta the highest. Dosages above 100 p/m produced liver injury. Kidney injury also occurred at high dosages. No lesions were produced at or below 50 p/m. (Morrison 1968).

Orr (1948) applied 0.5 percent lindane in acetone to the skin of mice twice a week for 15 months in a vain effort to produce cancerous lesions. Paraffin pellets with 3 percent lindane implanted beneath the skin for 10 months also failed to produce abnormalities.

Truhaut (1954, cited in FAO-WHO 1965) fed groups of 20 young rats on diets containing 25, 50, and 100 p/m of lindane for their entire lives. The highest dosage produced slight liver enlargement and fatty degeneration of the liver. No symptoms or lesions occurred at the 25 p/m level and no increase in the incidence of tumors occurred (Morrison 1968).

According to the Agricultural Board, Division of Biology and Agriculture (1969), mammals metabolize lindane quite rapidly to trichlorobenzenes and phenols, which are excreted.

^{3/} Hubbell, R. J. 1967. The effects of direct control on pine bark beetles in an urbanized forest. Report on file, Calif. Div. For. Dist. VI, Riverside Calif., 5 p., illus.

O' Brien (1967) reports very little lindane is accumulated in the body fat, and in mammals it has a low oral toxicity.

Fish

In our operational use of lindane, precautionary measures are taken to ensure that the spray does not directly, or indirectly, get into streams. Fish are less sensitive to BHC than to DDT, toxaphene, dieldrin, and other new chlorinated hydrocarbons. Brown and rainbow trout were all killed by exposure to 0.05 p/m of lindane, but bluegills have survived 0.45 p/m of 12 percent lindane. However, bass and bluegill fingerlings suffered 50 percent mortality at 0.1 p/m of the same formulation (Rudd 1956). Gakstatter and Weiss (1967) report that four species of fish were exposed to water containing 0.03 p/m lindane. Two days after termination of exposure, the fish had eliminated 90 percent of the lindane.

Generally most insecticides are toxic to fish. The chlorinated hydrocarbons are particularly toxic. However, lindane is considered to be one of the safer chlorinated hydrocarbons (O' Brien 1967).

Humans

Evidently very little work has been done with lindane in relation to human health. Our field procedures on the use of lindane were explained to Dr. Kopping, U.S. Public Health Service, in January 1967. It was his belief that field workers would not show any lindane in the system using current Forest Service procedures. He said that lindane is rapidly eliminated from the body and he would not expect any accumulation unless the patient had been subjected to repeated acute exposure. O'Brien (1967) reports that a Rumanian study showed no ill effects from massive inhalation of DDT plus lindane in a forest spraying operation; some workers inhaled 21 mg/kg of DDT as well as 6 mg/kg of lindane daily for 30 days.

Hayes (1963) states that lindane (gamma isomer of BHC) has the greatest acute mammalian toxicity of all the isomers of BHC. However, it is rapidly excreted by the kidneys and does not accumulate extensively. Lindane has the lowest toxicity on repeated exposure, and therefore is safest for use by workers under long, intensive exposure.

METABOLISM OF LINDANE

There is much concern about the toxic effect of the metabolites of organochlorine compounds. Dr. Francis Gunther (personal communication) said that to his knowledge none of the metabolites of lindane have any toxic side-

effects. One of the more common metabolites is pentachlorocyclohexene (PCCH), which was confirmed by Yule (1967). This is the common degradation product in soils. (Guenze 1970). In mammals lindane is metabolized quite rapidly to trichlorobenzenes and phenols, which are excreted (Agricultural Board 1969).

RESIDUAL LIFE OF LINDANE

Certainly, as well as its toxicity, the residual life of lindane makes it a desirable insecticide for bark beetle control. Obviously, since bark beetles emerge over a long period of time an insecticide with a short residual life would not be effective.

Lindane applied as a lindane-diesel solution forms a tissue deposit. Lyon (1969) states that tissue deposits of lindane have several advantages over surface deposits: (a) toxicity is higher to the target insect, (b) residual life is longer, and (c) less lindane is available to bark beetle predators and parasites. In contrast, when lindane was applied as a wettable powder at 40 mg actual per square foot, forming a surface deposit, all toxicity was lost in six weeks. (Lyon 1965).

The residual life of lindane as a preventive has been well documented. Smith (1970) reports a 2 percent lindane oil solution applied on ponderosa pine bark remained effective against *Dendroctonus ponderosae* and *D. brevicomis* for three years. Also, according to Swain^{4/} a 1.5 percent lindane-water emulsion gave effective protection against *D. brevicomis* for at least 9 months and probably longer when applied to the bark of standing ponderosa pine.

Dr. William Spencer (personal communication) believes that lindane in soil has very little movement downward. He feels that a 1.5 percent lindane spray on forest soils would volatilize and degrade quite rapidly. And, as long as there is soil moisture, lindane volatilizes readily at 30° C and above. The published vapor pressure of lindane at 30° C and 55° C is 4.5 x 10⁻⁵ and 1.45 x 10⁻³ mm of mercury. Spencer (1960) found the vapor pressure to be 3.5, 2.0, and 2.4 times greater at 20°, 30°, and 40° C, respectively, than the published values. Guenze (1970) reports that lindane degrades in soil to pentachlorocyclohexene, which is more volatile than lindane, and does not remain in the soil to any extent.

^{4/} Swain, Kenneth M. 1968. Protecting ponderosa pine from bark beetle attack using lindane-water emulsion spray. Report on file, Div. Timber Manage., California Region, U.S. Forest Serv., San Francisco, 13 p.

As used in bark beetle control, lindane can have an effective residual life of up to three years. The residual life is dependent upon the concentration, solvent, and type of material being sprayed. From current information it is apparent that lindane is quite variable in its rate of degradation. The current field application of lindane should have a minimum adverse effect on the environment.

FUTURE USE OF LINDANE

Certainly it would be desirable to find alternative methods for treating bark beetles. Hopefully, pheromones will lead to a method of control whereby insecticides will not be needed. New research can help us recognize and conserve the natural enemies of bark beetles. In all probability, however, the need for insecticidal control cannot be eliminated. Now is the time to quit talking about so-called "integrated control" and to put it into practice.

According to Lyon (1971) Dursban, Zectran, and malathion show promise in laboratory tests against the western pine beetle. Let us field test these insecticides. However, until an effective replacement for lindane has been adequately tested, the continued use of lindane is necessary.

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PESTICIDE SPRAY APPLICATION,
BEHAVIOR, AND ASSESSMENT:
WORKSHOP PROCEEDINGS



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Pesticide Spray Application, Behavior, and Assessment: Workshop Proceedings

March 1-2, 1973

Emeryville, California

Technical Coordinator

Richard B. Roberts

Coordinating Staff

Patrick J. Shea, Robert L. Dimmick, Alvin M. Tanabe

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1976. Pesticide spray application, behavior, and assessment: workshop proceedings. USDA Forest Serv. Gen. Tech. Rep. PSW-15, 68 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Experts from relevant disciplines exchanged information on three important problems of pesticide spray technology. The four papers presented are *Physical Parameters Relating to Pesticide Applications* by N. B. Akesson and W. E. Yates; *The Micrometeorology and Physics of Spray Particle Behavior* by H. E. Cramer and D. G. Boyle; *Impact of Zectran Particles on Spruce Budworm Larvae: A Field Experiment* by J. W. Barry and Others; and *Assessment of Insecticide Spray Processes* by C. M. Himel. Summaries of the three workshop sessions are also included.

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Retrieval Terms: Spray applications; insecticides; pesticides; spray particles; models; zectrans; aerosols; transports.

TECHNICAL COORDINATOR

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COORDINATING STAFF

PATRICK J. SHEA, a research entomologist at the time of the workshop, is now supervisory research entomologist in charge of the Station's Field Evaluation of Chemical Insecticides. He joined the Station staff in 1967, and earned the M.S. degree in forest entomology in 1974 at the University of California, Berkeley. ROBERT L. DIMMICK, a research bacteriologist, is chairman of the Aerosol Sciences Department of the Naval Biosciences Laboratory, Oakland, California. He holds a doctorate in microbiology from Purdue University, Lafayette, Indiana. ALVIN M. TANABE was formerly an assistant research entomologist at the Naval Biosciences Laboratory. He holds a doctorate in entomology from the University of California, Berkeley.

PREFACE

The purpose of this workshop was to bring together experts from all scientific disciplines to exchange information and ideas on three of the most important problems of pesticide spray technology -- application, behavior and assessment. The broad range of scientific talent represented and the scope of the effort needed to keep abreast of this field are evident from the list of participants in the workshop.

There has been a growing tendency to emphasize the importance of controlling the spray cloud and the droplet (particle) size and the necessity of monitoring meteorological conditions. Increased concern over aerial application technology has developed for several reasons, including: (1) use of pesticides that biomagnify and adversely affect nontarget organisms, (2) increased use of transient insecticides and decreased use of residual insecticides, (3) increased awareness of the pollution problems resulting from drift and (4) increasing knowledge of the effective particle spectrum of contact insecticides.

It was our hope that this workshop would provide a common meeting ground for the free exchange of information and ideas among the workshop attendees. Judging by the contents of these proceedings, an excellent start was made toward accomplishing this goal. Certainly, the response to the call for committee members to aid in developing standards and guidelines was a good indication of the enthusiasm generated by the workshop.

The workshop was sponsored by two organizations. The Insecticide Evaluation Project, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, was organized to develop safe, selective, nonpersistent, and effective materials and techniques to manage forest insect pest populations with minimal environmental effects. The program of research was divided into four problem areas: (1) screening and bioassay of candidate chemicals and formulations for selection of those most effective for control of specific insect pests; (2) chemistry and toxicology of selected chemicals, which includes synthesis and formulation of selected candidates, physiological and biochemical effects in insects, residue analysis, and spray particle behavior; (3) penetration, translocation, and metabolism of chemicals on and in forest trees to develop effective foliar systemic treatments; and (4) field evaluation of insecticide formulations to determine safety and efficacy.

The Naval Biosciences Laboratory, formerly the Naval Biomedical Research Laboratory, is a research unit funded in large part by the Office of Naval Research and the Bureau of Medicine and Surgery, United States Navy, and administered through the School of Public Health, University of California. Grants and contracts from other government agencies are also part of the funding structure. The Laboratory is located at the Naval Supply Center, Oakland, California. The primary specialty of the Laboratory is aerobiology and the study of respiratory disease and allied medical problems. Unique equipment and facilities have been constructed to permit the study of aerosols under highly controlled conditions, including the exposure of test animals to airborne particles.

The smooth functioning of the workshop would not have been possible without the aid of Patrick Shea of the Pacific Southwest Forest and Range Experiment Station, Berkeley, and Richard Dimmick and Alvin Tanabe of the Naval Biosciences Laboratory, Oakland. They provided assistance in planning the workshop and taking care of many details essential to its success. The help of Rose Marie Shea, Eileen Dimmick, Pat Tanabe, and Betty Roberts, together with staff members of the two organizations, who served as projectionists, chauffeurs, and secretarial assistants, was indispensable.

RICHARD B. ROBERTS



This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

WELCOME ADDRESS

Harry W. Camp¹

Welcome to this workshop concerned with pesticide spray technology. This meeting is particularly significant because of the use of chemicals in today's "atmosphere" of critical need for improving the production of food and fiber, in a situation where improvement of the quality of our environment and lowering of costs are every bit as critical. There are forces of men at work in both areas, and only through their cooperative efforts will we arrive at an acceptable solution to the problem of producing adequate supplies of food and fiber at acceptable costs in an environment suitable to all of us.

This workshop is a cooperative venture of the Naval Biomedical Research Laboratory,² Naval Supply Center, Oakland, California, and the Insecticide Evaluation Project, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. The general objectives of these two research units are outlined in your program so I shall not repeat them. Special credit is due to Mr. Allen Jewett, Head of the Microbiology Branch, Naval Biology Program, and Dr. William Waters, Head of Forest Insect Research, U.S. Forest Service.³ These two men from Washington D. C., are responsible for bringing together the two sponsoring units here in the Bay area. Locally, Dr. Richard Roberts and Mr. Patrick Shea of the Pacific Southwest Station, and Drs. Robert Dimmick and Alan Tanabe of the Naval Biomedical Research Laboratory are responsible for arranging the excellent program ahead of you.

I would be happy to dwell at length on the importance of the research being done in pesticide application, behavior, and assessment, but the fact you are here leads me to believe you are well aware of its importance.

It is with a great deal of pleasure I welcome you, on behalf of Dr. Neylan Vedros, Director of the Naval Biomedical Research Laboratory, and myself, to Berkeley and to this workshop on Pesticide Spray Technology. May you have a highly successful meeting.

¹At the time of the workshop, Mr. Camp, now retired, was Director, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

²The Naval Biomedical Research Laboratory is now the Naval Biosciences Laboratory.

³Dr. Waters is now Dean of the College of Natural Resources, University of California, Berkeley.

APPLICATION

Physical Parameters Relating to Pesticide Application

Norman B. Akesson¹ Wesley E. Yates¹

ABSTRACT--Integrated control of crop-damaging insects includes judicious application of pesticides. Dispensing equipment is available in wide variety to produce various drop sizes ranging from aerosols to coarse sprays. Size ranges and frequency distributions of drops produced by different types of equipment have been determined. Actual field deposit and insect contact rates are affected by chemical, physical, and biological factors. Ultra-low-volume spray techniques are being increasingly used, with varying success. Local meteorology, particularly temperature inversions, strongly affects spray dispersion and helps to determine suitable times for application.

A host of measures have been used in man's never-ending fight to protect his health and that of his domestic animals, and to protect and insure an abundant food supply in the face of an ever-increasing population and demands for a higher standard of living. In recent years, the widespread occurrence of pesticide chemicals in the environment, along with increasing pollution from industrial and agricultural sources has caused increasing concern for protection of the environment as well.

The folly of total dependence on any one of the many measures available for pest control, such as our recent overuse and reckless use of pesticide chemicals, has been clearly demonstrated by nature's reaction to such poorly designed measures. Examples are the development of insect resistance and the even more dangerous elimination of parasites and predators beneficial in controlling our economically important insects. Under these changed conditions, such insects can quickly destroy a crop despite frequent applications of larger and larger amounts of the most toxic chemicals.

This problem has led to a return to total crop management, or what is called integrated control. This is not a new concept, but one that was, of necessity, widely practiced before synthetic pesticides were available. The concept has been defined as the use of combinations of physical, biological, and chemical measures that have been found to

supplement and enhance one another, so that the coordinated efforts may achieve the highest degree of effective control. Thus, integrated control includes crop management, management of waste disposal and sanitation, and irrigation and drainage control, in addition to management and monitoring of crop pests, which includes consideration of seasonal and weather influences and biological means of control, and, most important, the judicious use and application of pesticide chemicals.

All these measures, normally directed toward maximizing crop production and reducing vector or forest insect population, must also be aimed at reducing the widespread indiscriminate use of pesticides, with their all-too-frequent injurious effect on the environment and the health of workers handling them.

New, more specific and biodegradable chemicals are needed, but there is also a need for greater use of biological control organisms, including predators, parasites, and microbial agents, as well as the more novel pheromones and juvenile hormones. These alone cannot overcome the pest problems today, or in the foreseeable future. But as part of an integrated control program, and especially in conjunction with chemical methods, they can achieve significant reduction in the need for chemical control, and substitute safer, less contaminating crop, forest, and vector control measures.

Important in careful pest control practices are (1) selection of chemicals best suited to the problems, but least damaging to the environment, (2) application of these at the proper time and place and in carefully metered dosages,

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and (3) application in proper formulation and particle size, with consideration of weather and geographic influences, and other factors, such as safety to nontarget plants and animals.

EQUIPMENT

Suitable equipment, and effective and efficient techniques for its use, are as important as the chemical or biological agent itself. A wide selection of equipment for dispensing various formulations is available. The decisions governing the selection of equipment are momentous and all too frequently poorly evaluated. Whatever is immediately available, or the most popular machine of the day, may be the choice. The biologist tends to blame his failures on the machine, but all too frequently he is not sufficiently aware of how the basic machine functions, such as what particle sizes it produces; he is not familiar with techniques of volume metering or application placement, and the relation of these to weather and terrain.

Solid formulations, as dusts and granules, offer a fixed concentration of toxicant and fixed particle size, and thus also a limited application or use. A few materials control insect or disease pests through systemic transfer of chemicals from foliage or roots to all parts of the plant. There is a larger choice of systemic herbicides. Of existing systemic pesticides, probably the safest least-contaminating type of formulation is nondusting large granules, or the microgranule or coarse dust, in which all particles below about 50 μm in diameter have been eliminated. Ground-operated equipment for granules are of several types; the conventional swath-width hopper, the centrifugal slinger (broadcast), and the air carrier (broadcast). For helicopters, slinger spreaders and air carriers are popular, but for fixed-wing aircraft, the ram air spreaders are probably most widely used.

Spray formulations offer a wide choice in toxicant strength, particle size, and total applied volume per application. For depositing-type sprays, and for vertical penetration of foliage, large particle sizes are found desirable as applied by pressure nozzle, boom, and offset nozzle equipment, as well as air carrier application machines. For finer sprays and aerosols, special types of equipment capable of high atomization energy are found desirable. These may be high pressure hydraulic nozzles, producing drops down to about 125 μm volume diameter (vmd), two-fluid (air and liquid) nozzles, or volatile-type two-fluid nozzles, which can produce atomization as fine as 10 to 15 μm vmd. Similarly, aircraft have been set up for all ranges of drop sizes of sprays and aerosols, and for a wide variety of application volumes from several gallons to a few ounces per acre. Obviously the equipment must be matched to the formulation, either dry or liquid, but much more particularly so when liquids are to be used for distinct and specified operations, such as adulticiding as opposed to larviciding in mosquito control.

Atomizers for liquid sprays and aerosols may be categorized as follows, by the source of the atomizing energy:

Pressure

Jet
Cone (hollow & solid)
Fan
Deflector fan
Offset

Centrifugal

Disk or cup
Brush
Screen or perforated cylinder

Gaseous

Vortical: low pressure, high volume
Shear
High pressure, low volume

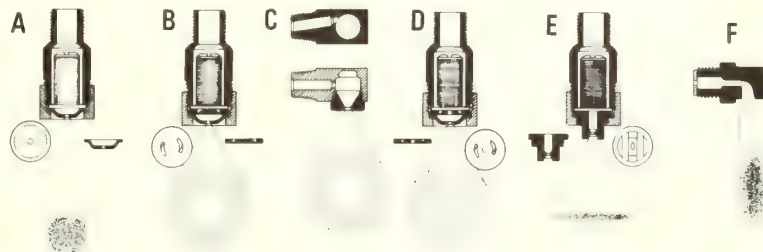


Figure 1. Pressure-type atomizers produce a wide range of drop sizes suitable for both aircraft and ground machine use. From left to right, (a) jet, (b) hollow cone showing whirl plate, (c) centrifugal-type hollow cone, (d) solid cone showing hole in whirl plate, (e) fan, and (f) deflector fan.

Pressure energy nozzles—The jet nozzle (fig. 1a) and the deflector fan nozzle (fig. 1f) produce sprays of large drop size. These two may be operated at pressures from a few pounds per square inch to a hundred or more, but to produce large drops with a minimum of small driftable drops, pressures should not exceed 5 to 10 lb/in². The use of these nozzles is confined to such applications as larviciding for mosquito control, or to low-drift-loss applications of herbicides by aircraft or ground equipment.

The fan and cone types are the most widely used pressure energy nozzles on aircraft or ground equipment. Drop size may range from 100 to 1000 μ m, varying primarily with liquid pressure. If liquid is discharged into an air stream, the air shear action increases the liquid break-up, increasingly so as the two streams approach 90 degrees or are directed toward one another. The fan types (fig. 1e, f) are most used with ground equipment where uniform cover is needed, whereas the cone types (fig. 1b, d), with stainless steel (hardened) orifices and whirl plates, are widely used with aircraft and air carrier ground equipment. Drop size ranges for cone types are from 125 μ m vmd to 500 μ m vmd.

Gaseous energy atomizers—The gaseous energy, two-fluid-type atomizers (fig. 2) are capable of sprays ranging from fine to aerosol-size particles. Pressures used may vary from a few pounds per square inch to several hundred, and because the energy required to produce an aerosol becomes rather significant in terms of the numbers of drops being produced, the aerosol-type atomizers are usually very sensitive to flow rates; drop size frequently increases rapidly as flow rate increases. Size range varies from 10 to 100 μ m vmd.

In the widely used cold fogger or vortical-type atomizer (fig. 3) air pressure seldom exceeds 5 lb/in², but air volume supplies energy at around 100 ft³/min for each nozzle.

Centrifugal energy atomizers—Rotary-type atomizers (fig. 4) include those with a perforated metal sleeve type driven by an electric motor; the widely used Micronair, which is air-propeller driven; and a smaller spinning screen device, powered by an electric motor. All of these produce fine sprays to aerosols, or a range of 300 to 50 μ m.

The centrifugal spinners have been used on both aircraft and ground equipment. However, they are susceptible to rapid wear and initial cost is high for good quality units.

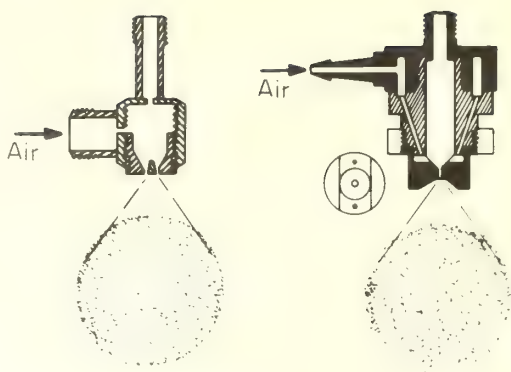


Figure 2. Two kinds of two-fluid atomizers are used: internal mixing (left), and external mixing (right). Both are designed for producing fine sprays and aerosols.

The spinners are very sensitive to flow rates, and increasing flow rate slows the air-driven types; the slower spinning, along with the increased flow of liquid, rapidly increases the drop size. Drop size range produced is similar to that of the two-fluid and hydraulic type atomizers; depending on the manner of operation.

In table 1, spray and drop size ranges and some of the atomizers that can be used to produce them are summarized. Pressures for liquid and air, and air speed for the rotary type nozzle, are also shown.

In table 2, for the various types of sprays and aerosols, and for the various drop sizes, the drop size distribution is shown, in cumulative percent. The 50 percent point corresponds to the volume median diameter² for the distribution of this type of spray, as produced by the nozzle specified in table 1.

The effectiveness of an aerosol is dependent upon the numbers of small drops, generally under 25 μ m, that are present. Thus it is easily seen why the aerosols are more effective for adulticiding; at least 97 percent of the drop volume is in drops below 20 μ m. In contrast, the very coarse spray,

²The volume median diameter is that size of drop which divides the total volume of drops found exactly in half; that is, 50 percent of the volume is in drops above that size and 50 percent below.

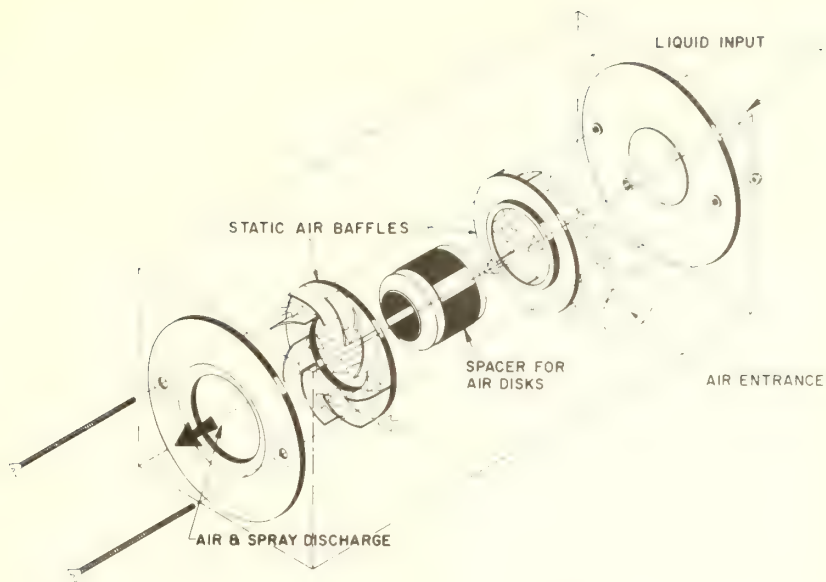


Figure 3. The vortical atomizer is shown here in an exploded view. Low pressure and high air volume produces aerosols as low as 10 microns volume median diameter.

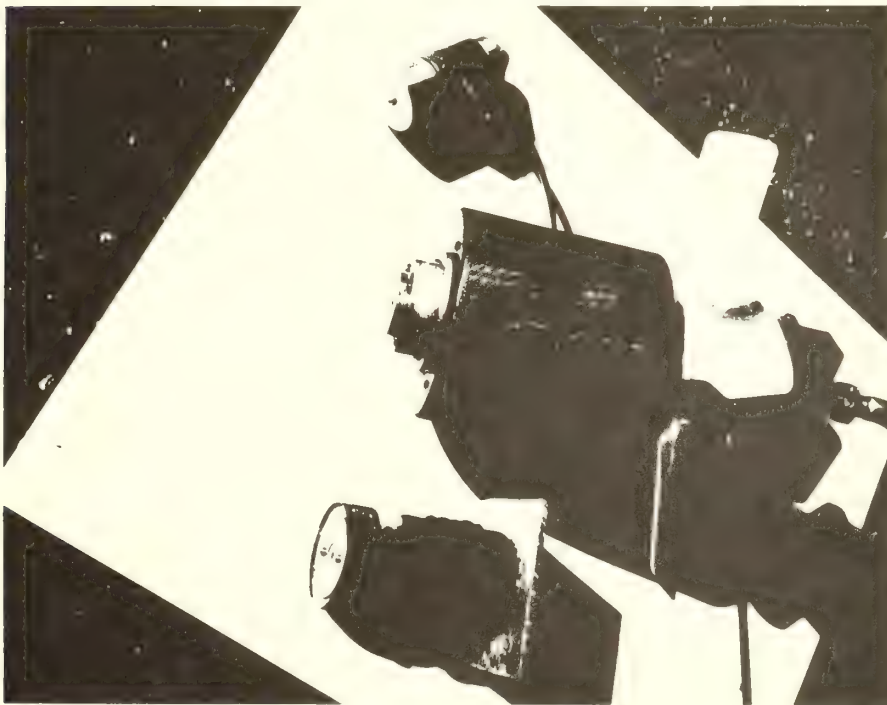
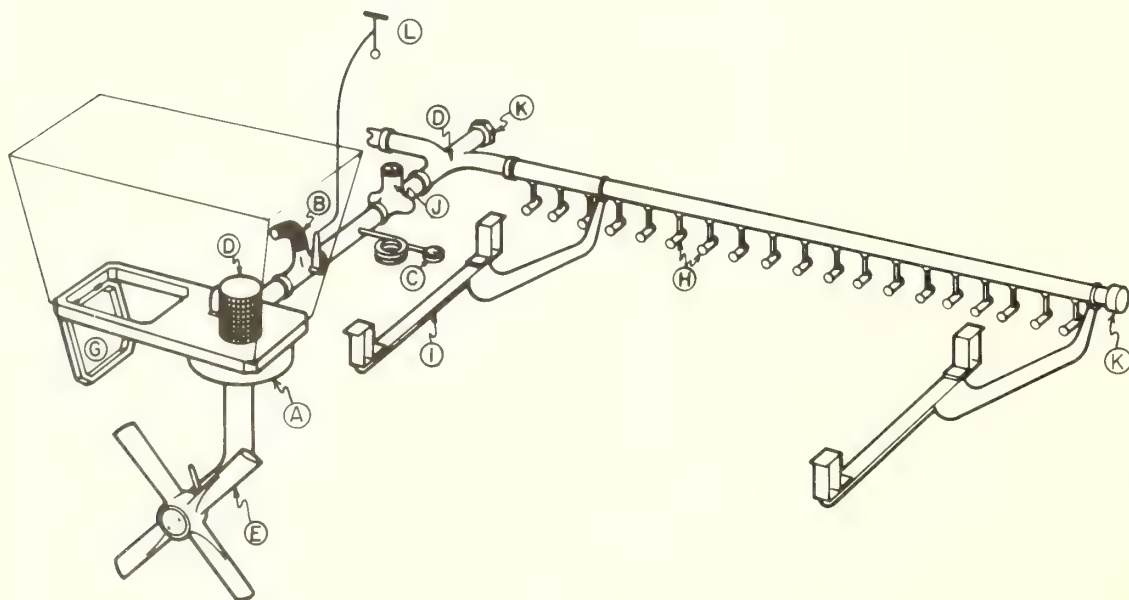


Figure 4. Three kinds of centrifugal or rotary atomizers are shown here. The device at top has a perforated metal sleeve, and is electrically driven. In the center, the Micronair air-driven type has a spinning screen. At bottom another spinner has a stainless steel screen, and is electrically driven.

Table 1--Summary of approximate spray and drop sizes produced by the various atomizers

Spray size	Drop size range	Nozzle type	Operating constant
	<i>Microns</i>		
Fine aerosol	Less than 50	Cold fogger	5 lb/in ² air psi
Coarse aerosol	50 to 100	Two-fluid	30 lb/in ² air psi
Fine spray	100 to 250	Rotary	90 to 100 mph air velocity
Medium spray	250 to 400	65015 Fan, down	40 psi
Coarse spray	400 to 500	D6-46 Cone, back	40 psi
Very coarse spray	More than 500	D6 Jet, back	40 psi



- | | | |
|-------------------|------------------------------|-------------------|
| A - Pump | E - Propeller | J - Liquid |
| B - Control valve | G - Dump gate | K - Boom cleanout |
| C - Pressure gage | H - Nozzles and check valves | L - Valve lever |
| D - Screen | I - Boom mount | |

Figure 5. This schematic diagram shows a basic aircraft spray unit. Included are a tank (outline), spray pump and propeller drive, and the control valve, which directs liquid to the boom and nozzle during spraying or back to the tank for recirculation.

Table 2--Drop size distribution of
aerosols and sprays, cumulative percent by volume¹

Drop size (μm)	Fine aerosols	Coarse aerosols	Fine sprays	Medium sprays	Coarse sprays	Very coarse sprays
<i>Cumulative Percent</i>						
1-5	5	0.1				
5-10	45	0.4	0.1			
<u>11</u>	<u>50</u>					
10-15	77	2.0				
15-20	97		2.0			
20-40	100	12.0		0.1		
40-60		35.0	5.0	2.0	0.01	0.001
60-80						
<u>86</u>		<u>50.0</u>				
80-100		59.0	15.8	6.0	0.1	
100-120						
120-140					0.4	0.1
<u>130</u>			<u>50.0</u>			
140-180		100.0				
180-200			81.0	17.0	3.0	
200-220						
220-240					7.0	5.0
240-260						
260-280						
280-300			100.0	46.0	14.0	
<u>278</u>				<u>50.0</u>		
300-350					24.0	
350-400					36.0	
400-450					46.0	
<u>460</u>					<u>50.0</u>	
450-500				92.0	55.0	
500-600					74.0	25.0
600-700					88.0	
700-800					96.0	
<u>900</u>						<u>50.0</u>
800-1000				100.0	100.0	100.0

¹The volume median diameter (underscored) is that size of drop which divides the total volume of drops found exactly in half; that is, 50 percent of the volume is in drops above that size and 50 percent below.

such as that produced by the jet back nozzle, directed with the airstream, is for low-drift-loss applications, and shows less than 0.001 percent of drop volume in drops less than 60 μ m (table 2).

Table 3, for aircraft use, summarizes drop size ranges and recovery rates. A complete aircraft spray unit is diagrammed in figure 5.

PARTICLE SIZE, DISTRIBUTION, AND COVERAGE

The success of pesticide applications depends largely on the particle size range of the spray or dry material, and on how this is affected by chemical, physical, and biological factors, some of which are described here:

1. The basic toxicity of the pesticide to the target pest. A small particle of a very toxic material may contain a lethal dose for the insect, whereas a larger drop or several small drops of a less toxic chemical may be required for lethal effect.

2. The physical characteristics of the chemical and its formulation, including density; flowability for dusts; and vapor pressure, viscosity, and surface tension for liquids. For liquids, these characteristics affect the initial atomization process, and the aerial transport, evaporation, and deposit of the drops.

3. The collection efficiency of target surfaces, such as insects, buildings, and vegetation. This follows Sell's law, whereby the collection efficiency (S) of an object is directly proportional to the drop diameter squared (d^2) and its relative velocity (V), but inversely proportional to the width or frontal area (D) of the object (figure 6). Thus, the collection efficiency of an object is increased rapidly by increased drop size and to a lesser degree by an increase in the relative velocity of the movement of the drop toward the object, but is decreased as the object size increases.

4. Location of the target insect, whether in the open or in a sheltered area, and in motion or at rest.

5. The local meteorological conditions. The presence and intensity of air turbulence, or the mixing and diffusion capacity of the air during application, greatly affect the dispersion of pesticides, particularly the small aerosol or airborne portions.

$$S(f) = \frac{d^2 V \rho}{D \mu}$$

$$S = \% \frac{d \text{ impacted}}{d \text{ available}}$$

d = drop diameter

V = drop to object velocity

ρ = drop density

D = object diameter

μ = fluid viscosity

(f) = object shape: plate > cylinder > sphere

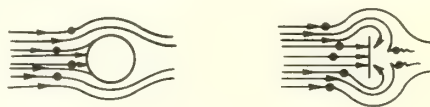


Figure 6. Sell's Law for deposit of liquid drops is illustrated here.

6. The type and characteristics of the ground cover. Grassy savannah or low-growing agricultural crops permit relatively unrestricted downwind transport of finely atomized sprays; increased bush and tree cover increasingly filters particles out of the air.

7. The characteristics of the application equipment, which determines the size range or frequency distribution of drops as well as the spatial distribution of all solid and liquid materials directed to the target area.

Generally, some optimum drop size range is recognized as most effective for each pesticide and for each formulation used for a specific vector control problem. Maximum effective control of the target organism with minimum use of toxic materials and minimum adverse impact on the ecosystem is the objective. This simple statement covers a highly complex physical and biological phenomenon that occurs during and following an area application of pesticides. Research toward the objective has been conducted over many years. The earliest work with Paris green and toxic botanicals progressed through petrochemical products, culminating in the extensive use of the synthetic pesticides, DDT and other organochlorines, as well as organophosphorous and carbamate materials.

Early observers found that although DDT and the other organochlorines are effective as direct contact applications, they are especially effective when used as residual applications. In contrast, many of the organophosphorus and carbamate compounds have a

Table 3--Spray drop size range, approximate recovery rate, and recommended use

Drop size or type and description of spray system	Typical nozzles and pressure ranges ¹	Drop size range ²	Estimated deposit in 1000 feet ³	Use
		<i>Microns $\mu\text{m vmd}$</i>	<i>Percent</i>	
Fine aerosols and fan nozzles, rotary atomizers	80005 down D2-13 down (200 to 300 lb/in ²)	less than 125	less than 25	Aerosol applications, in vector control and control of forest insects and agricultural pathogens; used at low volume rates, primarily for adulticiding
Medium sprays and fan nozzles, rotary atomizers	80005 down D6-45 down (50 to 100 lb/in ²)	100 to 300	40 to 80	Forest pesticide chemicals, in large-area vector control, at low dosages of chemicals with low toxicity and rapid degradation; also useful for agricultural insect pathogens
Coarse sprays and fan nozzles, rotary atomizers	D6-46 down (30 to 50 lb/in ²)	300 to 400	70 to 90	All low-toxicity agricultural chemicals where good coverage is necessary
Very coarse sprays and fan nozzles, with additives	D6-46 back (30 to 50 lb/in ²)	400 to 600 with additives up to 2000	85 to 98	Toxic pesticides of restricted classification, when thorough plant coverage is not essential
Sprays with minimum drift nozzles and with additives	D4 to D8 down at less than 60 mph; Back at over 60 mph (30 to 50 lb/in ²)	800 to 1000 with additives up to 5000	95 to 98	All toxic, restricted--class herbicides such as phenoxy-acids and others, within limitations such as growing season and location near susceptible crops
Sprays with maximum drift control turbulence nozzles	Microfoil (less than 60 mph airstream) ⁴	800 to 1000	99 or more	Restricted nonvolatile herbicides, phenoxy-acids and others in the area of susceptible crops, subject to limitations of growing season and type of crop

Ray Systems Co. nozzles; position on aircraft boom is indicated as "down" or with the airstream.

Determined with water base sprays; oils would give smaller drops.

100 feet downwind; wind velocity 3 to 5 mph, neutral temperature gradient; material released under 10 feet height. Drift tests, drift residue levels at 500 feet downwind for Microfoil were one-fourth those for D4 to D8 jets.

high contact and airborne toxicity to insects but degrade and lose effectiveness much more rapidly than the organochlorines, particularly in the presence of water.

Early researchers working on drop size presented data (verified in the laboratory and to some extent in the field) on the most efficient drop sizes to be used with given chemicals and on specified vectors. Latta and others (1974) calculated that the LD₅₀ for *Aedes aegypti* was obtained with minimum dosage when drops of 22.4 μm containing DDT were used with an air velocity of 2 mph past the mosquito. At 3 mph the drop size was found to be 18.3 μm , at 4 mph 15.8 μm , and at 5 mph 14.2 μm . Johnstone and others (1949) came to the conclusion that the most effective drop size of a 10 percent DDT oil solution for control of resting and flying mosquitoes considering both impaction rate and lethal dose would be 33 μm . This, however, is still below the minimum drop size (83 μm) containing a lethal dose of DDT and, therefore, is a compromise size; impingement of several such drops is required to kill an individual mosquito.

Yeomans and others (1949) calculated from the Sell's law relationship (fig. 6) that a mosquito having a frontal width of 0.025 inch, at 2 mph air velocity, would collect 15.8 μm drops most efficiently. This size is somewhat smaller than Latta's 22.4 μm for 2 mph, because Latta used a smaller frontal width for his model mosquito. It has been shown in recent studies by Weidhass and others (1970) that with the newer highly toxic organophosphate materials, an LD₁₀₀ lethal dose for *Aedes taeniorhynchus* can be obtained from a 25- μm drop of malathion, a 17.5- μm drop of naled and a 20- μm drop of fenthion. These sizes are much closer to the size of drops earlier observers found to be most efficiently collected by small insects; such drops did not contain lethal doses of organochlorines, however. Sell's law shows that the minimum optimum drop size (the size of the drop most efficiently deposited) increases for larger insects. Thus houseflies showed increasing collection of drops up to 22.4 μm (David, 1946) and locusts up to 60 μm (McQuaig, 1962).

Drops carried by an airstream approaching a small object, such as a cylinder 1/8 inch in diameter (representing an insect body), are quite small in relation to the object (5 to 100 μm in relation to 0.318 cm, for

example). Such drops tend to be diverted in two streams around the object. Only those drops directly in line with the center of the object will be deposited (fig. 6). As the size of drops or their velocity increases, those drops approaching in the projected frontal area of the object are less likely to be drawn around it by the airstream and are also deposited. The collection efficiency (S), expressed as percent, is the number of drops caught by the object divided by the number of drops approaching the object in its projected width. The graph of the concept of Sell's law of drop collection efficiency (fig. 7) shows that a 0.318-cm object has about a 30 percent collection efficiency for 10- μm drops moving at 10 mph, but a 70 percent efficiency for 25- μm and a 95 percent efficiency for 100- μm drops. Because the larger 1.27-cm (1/2-inch) cylinder deflects larger drops, the 50- μm drops at 10 mph are collected with about 62 percent efficiency and the 100- μm with about 85 percent efficiency. When the drop velocity is decreased, as from 10 to 5 mph, the collection efficiency of objects decreases more rapidly for smaller than for larger drops.

These indications of the size of the smallest drops for near-maximum collection efficiency serve only as a guideline for actual spray application. In the field, not only is the aerosol or spray dispersed in a range of sizes, but also the chemical, physical, and biological factors discussed earlier affect the movement and deposit of the drops.

Earlier observers tried to evaluate application machines and techniques in relation to type of ground cover and weather in actual field trials. Johnstone and others (1949) developed theoretical data based on atmospheric diffusion equations which indicated that if 10- μm drops are released at ground level, cumulative recovery (deposit) out to 6 miles would never exceed 60 percent under conditions of a small temperature inversion with 2 mph velocity. At 5 mph velocity with no inversion, the recovery could be under 36 percent. Yeomans and others (1949) showed from field studies that an aerosol with a vmd of 50 μm deposits up to 60 percent in 2000 feet under temperature inversion conditions, but less than 23 percent with more turbulent or lapse weather. Tables 4 and 5 provide data on the deposit rates of various drop size ranges and swath widths attained by dispersal of pesticides from aircraft and from ground equipment.

Table 4--Calculated deposit rates and swath widths of various drop-size ranges of sprays applied by aircraft at various heights above the ground (neutral or small temperature gradient; wind velocity 3 to 5 mph)

Drop-size range (vmd, μ m)	Estimated deposit within 1000 ft	Estimated downwind swath width at release height (feet) of...					
		10	25	100	250	500	1000
	<i>Percent</i>	<i>Feet</i>					
400	80 to 90	50	70	125	400	750	1500
250 to 400	60 to 80	100	150	350	750	1500	2000
100 to 250	40 to 60	250	350	650	1500	2750	1 mi
50 to 100 ¹	15 to 40	1000	3000	5000	1 mi	2 mi	2 mi

¹Spray applications with vmd's under 100 μ m are not practical from aircraft because of extensive aerial drift.

Table 5--Calculated deposit rates and swath widths of various drop-size ranges of sprays applied by ground equipment (neutral or small temperature gradient; wind velocity 3 to 5 mph)

Drop-size range (vmd, μ m)	Deposit (cumulative) downwind ¹				
	49 ft	98 ft	327 ft	457 ft	984 ft
	<i>Percent</i>				
10	0	1	3	3.3	3.5
25	1.0	1.5	5	10	13
50	10	25	30	35	38
100	25	50	70	75	80

¹Dispersal of pesticide made at 3 feet above the ground.

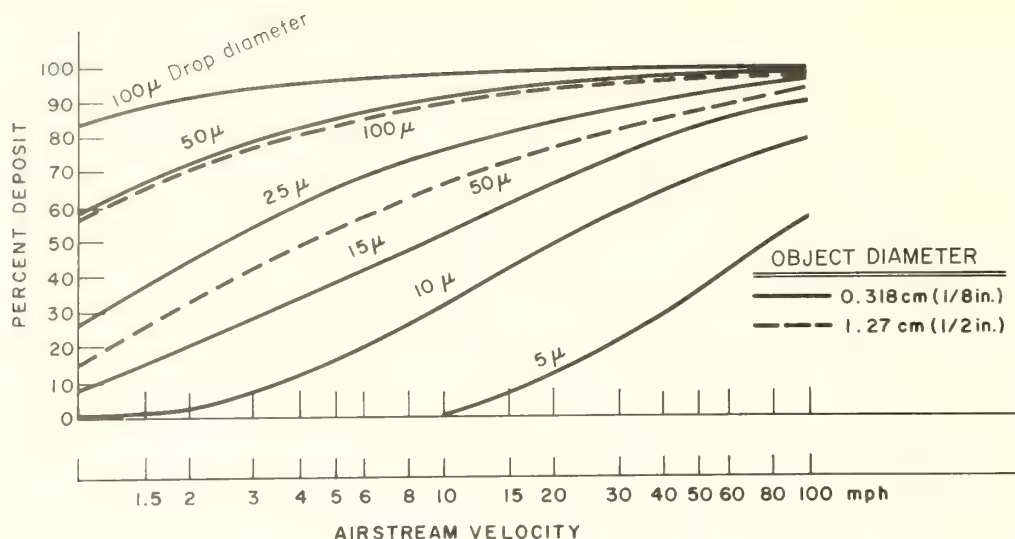


Figure 7. The calculated deposit rate (percent) of liquid drops of two different sizes traveling at different air velocities onto small objects is graphed here.

APPLICATION VOLUME

Liquids may be applied in dilute or concentrated form. Dilute sprays are most frequently used for large-volume applications as large drops and with a wetting coverage. Concentrated liquids, generally those with very little or no diluting carrier are applied as a fine spray, mist, or aerosol. Ultra low volume (ULV) is another name for the concentrate-type aerosol sprays; it covers a wide range of volumes and dilutions of applied sprays, from a fraction of an ounce to a pint or more per acre.

The ULV treatment is a technique for applying a minimum amount of liquid per unit area compatible with the requirements for achieving control of a specific organism with a specific chemical. Whenever small volumes are applied, the liquid is finely atomized in order to maintain a desirable number of drops per unit of area or per unit of space volume. The number of drops available from a given volume of liquid is inversely related to the cube of the drop diameter. That is, if the volume is held constant the following relation holds true, in which N_1 and d_1 are the initial number and drop size and N_2 and d_2 are the new number and size:

$$N_2 = N_1 \left(\frac{d_1}{d_2} \right)^3$$

This relation is more forcefully shown by the data in table 6. The values shown are for absolutely still air (virtually nonexistent outside of a closed laboratory). The table is based on the Stokes' law calculation frequently used by theoreticians to describe downwind transport of small drops. However, this is not a practical calculation for field operations, since in the outdoor air, even under a very calm temperature-inversion condition, the air is continuously in motion, and rising air currents will keep drops as large as 50 μm suspended, not for the calculated 50 feet or so in a 1 mph wind when released at 10 feet height, but for several hundred feet before falling to the ground. As can be seen from table 6, a 150 μm diameter water drop has a fall velocity of 1.5 ft per sec or about 1 mph. Thus, a 1-mph vertical air motion would keep such a drop supported indefinitely. Under field conditions, the wind will move up and down as well as travel horizontally and drops will be forced downward and deposited by these air movements as well as lofted by rising air.

From an application volume of 1 gal/acre, if all drops were spread uniformly, the number of drops per unit of surface area per square inch will vary as the diameter cubed (table 6). Thus, a 20-μm diameter drop size would produce 140,000 drops/in² at 1 gal/acre, while a 50-μm drop size would give only 9100. This points out the tremendous covering power of small particles, which permits thorough exposure of target organisms or other surfaces

Table 6--Terminal velocities of water drops¹ in still air and numbers per given volume in relation to unit area and air volume.

Drop diameter in microns	Terminal or steady- state velocity	Number of drops at applied rate of 1 gal/acre		
		At surface	In air to depth of 33 feet	
	<i>Ft/sec</i>	<i>Per in²</i>	<i>Per ft²</i>	<i>Per in³ air</i>
1	0.01×10^{-2}	1153.0×10^6		110.0×10^2
5	0.25×10^{-2}	91.8×10^6		85.0
10	1.0×10^{-2}	1.15×10^6		11.0
20	4.0×10^{-2}	0.14×10^6		1.3
50	0.25	91.0×10^2		0.08
70	0.4	34.0×10^2		0.033
100	0.9	11.5×10^2		0.011
150	1.5	3.5×10^2		---
200	2.5	1.4×10^2		---
300	3.8	43.0	6193.0	
500	7.0	9.0	1311.0	
1500	13.0	1.13	162.0	
2000	21.0	0.14	20.2	
5000	30.0	0.09	13.0	

¹Solid particles would have approximately same terminal velocity and numbers, but these would vary somewhat, depending on the density of the solid.

to the small volumes of applied aerosols. It is to be noted, however, that deposit of aerosols is limited by application conditions. Carrying this calculation one step further, the number of drops per cubic inch of air to a depth of 32.8 feet from a 1-gal/acre application is shown in the far right column, considering all the drops are of one size and uniformly dispersed. Again the cube relationship exists, and with 20- μ m diameter drops, 1.3 drops/in³ would be found, while at 50- μ m-diameter only 0.08 drops/in³ would exist; thus, space sprays, directed specifically at a small target organisms such as a mosquito, require the use of drops under 50 μ m diameter for adequate coverage. It should of course be pointed out that no atomizer system produces drops of one size, and for such calculations relating drop size to vector control, the normal or skewed Gaussian distribution of drops, covering a wide range of, for example, from less than 1 μ m up to 50 μ m for a 20 μ m vmd, usually exists.

Ultra-low-volume techniques are generally concerned with space spray as well as deposited spray, and so the drop size produced is in the range of aerosol and mist except in special cases where large drops can be used at a very low spatial distribution. A variety of machines using (1) high liquid pressures, (2) airshear such as that produced by high-speed aircraft or airstreams, and (3) various two-fluid and spinning devices are available for producing the fine drops required for ULV applications.

Large scale, low-cost mosquito control programs have been adapted to ULV techniques particularly for emergency treatment when entire cities or other large areas are treated. Increasing use is being made of ground aerosol equipment for ULV-type treatments. Utilizing the "drift spraying" techniques, aerosols of vmd below 50 μ m can be carried by prevailing winds for downwind distribution in open areas from 1000 feet to

a mile or more. However, the success of such applications is wholly dependent upon a temperature inversion condition that will restrain any vertical diffusion of the spray-laden cloud. It must also be appreciated that evaporation of the released aerosol must be kept to a minimum by use of low-volatility spray formulations. Applications of aerosols under 50 μm vmd by aircraft have shown erratic results; only under unique weather conditions will the pesticides under 50 μm settle toward the ground in sufficient numbers to produce either a detectable deposit or provide an adequate number of drops for space sprays. The use of thermal aerosols where a significant portion of the released aerosol is in particles below 5 μm as a smoke or fog is being replaced with aerosols mechanically produced for elimination of the wasteful and sometimes hazardous smoke of thermal machines.

A number of sources have been utilized to provide representative data in tables 4 and 5 concerning the fallout of various-size drops applied from the air and the ground. The estimated downwind recovery for aerosol size particles (under 50 μm vmd) is shown in table 5. Since aerosoling for adult insect control is largely by direct insect-drop contact, the most effective drop size would have to be small enough to impinge on the small surface presented and to remain airborne for a sufficient time for insect contact to take place.

Table 7 illustrates the size range and coverage capabilities of various grades of granular materials. Dust materials are generally made up of particles below 25 μm diameter (or longest dimension) and their characteristics would follow those of liquid drops of a similar density.

Table 4 presents data for aircraft distribution of various-size drops. The approximate downwind spread or swath width in feet of the released spray indicates where significant amounts of residue could still be found when spray is released at various heights. Thus, it is shown that for a coarse, rapidly falling spray at 400 to 500 μm vmd, the swath width is only 50 feet when spray is released at a 10-foot height, but increases to 1500 feet when spray is released at a 1000-foot height. For smaller drops of the mist category (50 to 100 μm vmd), the swath width at a 10-foot release height is 1000 feet, and at a 1000-foot release height may be 2 miles or more. Sprays or aerosols under 50 μm vmd, as noted earlier, are too unstable when applied by aircraft to be used anywhere except under highly controlled situations where supervisory personnel know the local weather conditions and can establish adequate vector control with such type of applications.

In summary, a very complex physical-chemical-biological system exists when chemicals are used for controlling insect vectors of human and animal disease. This system can be understood through using the knowledge and proficiency of the several scientific disciplines involved, including physics, meteorology, chemistry, engineering and entomology. It should be noted that the aerosol drop size which provides greatest coverage and potential adult insect contact is also the most susceptible to air transport, depending on local meteorological factors.

METEOROLOGY AND PESTICIDE APPLICATION

The local meteorology can be a significant factor controlling the success or failure of a vector control operation. The basic parameters are (1) temperature gradient or change with height, (2) wind velocity and wind velocity gradient with height, (3) wind direction during drift spraying or aerosoling, and (4) relative humidity as it relates to spray drop evaporation, particularly if water is the pesticide carrier.

These factors affect the rate of dispersion of pesticide materials release from either ground or aircraft equipment. The most significant of the factors listed is the temperature gradient. When the air overhead is warmer (which may occur at various levels) than that at the ground, any material released at the ground and transportable by air, such as aerosol particles smaller than 50 μm , will be carried by the moving air along at ground level and will not diffuse upward. The air velocity under the inversion layer will control the mixing process in the area and higher velocities will cause more rapid ground level dispersion. When temperature gradients are increasingly cooler overhead above a warm ground, the spray can easily be diffused upward and is rapidly dispersed and diluted by wind.

Temperature inversions (fig. 8) with low wind velocity and velocity gradient provide the greatest vertical confinement of released sprays, and thus the best application conditions, particularly for fine sprays, mists, and aerosols, when a large proportion of the released material is airborne size. This means that the time for application of aerosols, in particular, and for best success with fine sprays and mists, as well, should be early morning to mid-morning, and late afternoon and evening, when the inversion condition can be shown to commonly exist. Coarse sprays may be applied at any time during the day, the only limitation being the wind velocity, which will displace the aircraft swath significantly when

wind exceeds 12 to 15 mph. This high wind also makes ground applications difficult to manage. Downwind concentration (essential for aerosoling) is rapidly reduced by temperature lapse (temperature gradient decreasing with height) and windy conditions; hence this condition is favorable to least downwind contamination in combination with a coarse spray.

Temperature inversions are produced by several means and frequently more than one means may be causing this effect. The most common is radiation inversion caused by the heat loss or radiation by the ground to a cool sky (when the sun is low or below the horizon); this heat loss cools the ground and air close to it during the day. Another important inversion cause is the influx over the land of a late afternoon sea breeze along coastal areas. This cold air moving up valleys over the ground pushes under the warm air and causes a temperature inversion condition. A third cause of temperature inversion conditions is subsidence, the phenomenon by which air from a higher elevation is forced down into a lower level, such as a valley. This drop in elevation warms the air and places a warm layer over a valley to produce this temperature inversion condition.

Because of the dominant effect of insolation, the inversion and lapse conditions follow a diurnal pattern, with lapse and neutral (no change in gradient with height) conditions prevailing during the day while the sun's effect is strong, and the inversion condition taking place when the sun is low during early morning and evening hours or at night (fig. 8). During cloudy overcast weather, the temperature gradient will vary from neutral to inversion condition, depending on cloud density and the two other gradient-affecting conditions.

Turbulence of the air is a normal daytime phenomenon which lessens under late afternoon temperature inversion conditions, and generally also at night when the sun's heating of the ground is not contributing to vertical movement of the air. It is possible to have turbulence under a strong temperature inversion, but normally this tends to stabilize the air. Even more stabilizing is forest or overhead canopy. Here the temperature will frequently remain the same (neutral with height) to the top of the forest cover. The wind velocity will be but a fraction of that above the forest cover and applying an aerosol by ground under the cover offers a realistic approach to insect control. Normally, outside (or above) the forest cover,

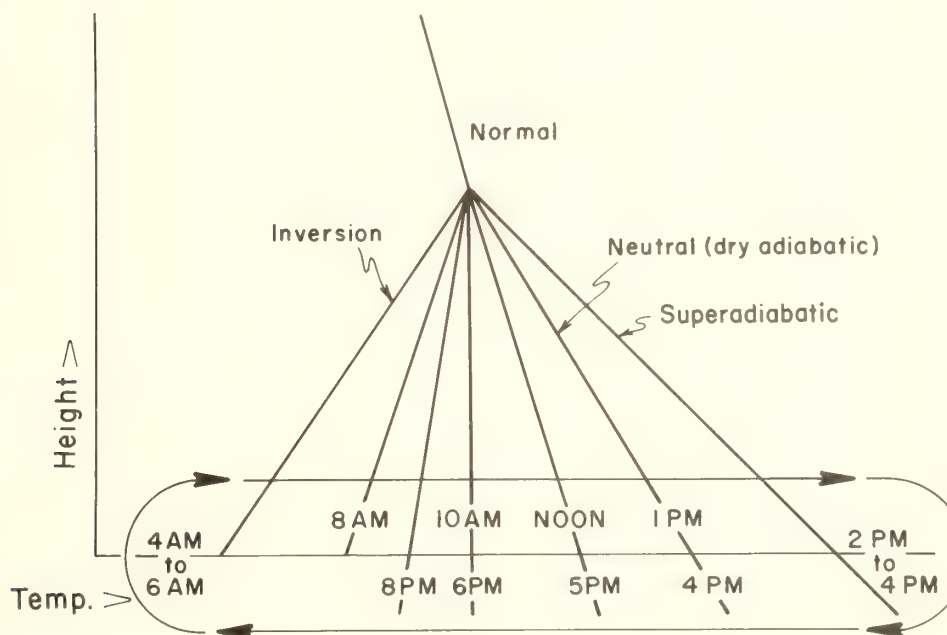


Figure 8. The diurnal variation in temperature gradient affects the dispersion of pesticide materials.

the usual daily changes in temperature and wind gradients will exist, with temperature inversions in early morning and late afternoon and daytime temperature lapse of turbulent mixing on most sunny days. During the night and under cloudy overcast, neutral conditions (neither strong lapse or inversion) would likely predominate.

Johnstone and others (1949) determined both horizontal and vertical (as discharged from an aircraft) forest penetration distances in terms of the percent of discharged aerosol that penetrated the forest to a stated distance, which he showed to vary with the density of the foliage cover. A very dense forest might have a vertical density of twice that of its horizontal density, owing to arrangement of leaves. He also shows that aerosols applied above the cover and having little downwind velocity do not penetrate but impinge on the foliage by horizontal wind motion. However, these aerosol drops do penetrate horizontally if dispersed under the cover, as with a ground aerosol machine. Penetration, however, would still vary with the density of the cover. For example, 15- μ m aerosols released near the ground under inversion weather conditions and 1- to 2-mph wind velocity gave deposits of DDT in the open (no cover) for a distance of 2000 feet. However, with light forest cover this distance was reduced to 600 feet, and in dense jungle growth the distance was further reduced to 200 feet of effective deposit. His data also shows that increasing the drop size to 200 to 300- μ m increases their vertical penetration through a forest canopy, but that most of those drops penetrating go to the ground. For mosquito larval control, sprays of 200 to 400 μ m vmd are quite effective by reducing losses to aerial drift and getting the highest deposit in the water. Filtration by rice foliage up to 3 feet tall had very little effect on the penetration of a 200 μ m vmd spray. Bioassay of chemicals in paper cups that were placed at the top of the rice and also in the water beneath plants showed little difference, although both the recoveries were unexpectedly low, varying from 10 to 45 percent of the applied spray (Akersson and others 1972).

Brescia (1945) was one of the first researchers to try to evaluate downwind transport and particle size in both adult and larval mosquito control. His tests involved thermal aerosols of 5 μ m and 16 μ m vmd. His results showed effective larva control of *Aedes taeniorhynchus*, also *A. sollicitans* and *Anopheles quadrimaculatus* at 0.001 to 0.002 lb/acre of DDT to distances of 2000 feet during strong inversion weather, and with grassy ground cover but no overhead canopy. Under a light forest canopy this

effective distance was reduced to 1100 feet, and for a dense forest, to 400 to 500 feet. For spray drops-to-adult or air-to insect contact, an aerosol under 10 μ m vmd, applied under strong inversion (but with a positive low wind drift), was effective to about 1 mile distance in the open areas, to around 1/2 mile under light forest, and 500 to 1000 feet under dense forest conditions. In any application downwind, the number of airborne drops and those deposited on the ground are increased by an increase in the applied dosage. Thus, the foliage obviously has a selective filtering capacity and permits a given percent of aerosol to pass no matter how dense the foliage may be.

Kruse and others (1949) used engine exhaust thermal aerosol generators on a Stearman type aircraft. With drop sizes of 35 to 40 μ m vmd, recovery on glass slides placed in the open in a 200-foot recovery swath, under near dead calm conditions, was 9 percent of the discharged spray, and the peak was only 12 percent at the center of the swath. Kruse's foliage penetration data is not available, but he indicates that the dose required for heavy, tall forest canopy would be 10 times that for the open field, while for moderate low foliage or grass cover he suggested five times the open area dosage for LD₉₀ control.

A wealth of information has been developed, mostly since 1960, on field use of the organophosphorus insecticides applied as technical concentrates or carried in nonvolatile petroleum and glycol solvents and diluents instead of volatile water base emulsifiable concentrates of solutions. With technical or near-technical concentrations of active ingredients of very high intrinsic toxicity, the phosphate and carbamate chemicals have made possible the reduction of liquid applied per unit of area to very low levels of 1 to 3 oz/acre, commonly referred to as LV (low volume) and ULV (ultra low volume) applications. However, it should also be pointed out that using these low application rates necessitates small drop size (under 100 μ m) to give an effective 8 to 16 drops per in² on flat surface, or under 25 μ m to give air volume (up to 33 feet height) dosage of 30 to 40 drops per in³ (table 6).

Recent literature suggests that the effective downwind range for a ground aerosol applicator using organophosphorus chemicals for adult mosquito control can be as far as 2 miles or more in open areas (Mount and others 1971) when drops of 10 to 15 μ m are released. Dosages of technical nonvolatile phosphate chemicals for caged and natural adult mosquito mortality of 75 to 100 percent vary from 0.1 to 0.001 lb/acre, depending on vector and chemical (Mount and others 1968). Recent data on the effect of dense and heavy forest or jungle growth on filtering of

Table 7--Deposit characteristics of various sizes of pesticide granules

Mesh size (Tyler sieve)	Size of mesh openings	Average number granules per pound	At dosage of 1 lb/acre, number granules deposited per ft ²
	<i>mm</i>		
8/16	2.36/0.99	145 × 10 ³	3
16/32	0.99/0.495	1,150 × 10 ³	26
20/35	0.833/0.417	2,708 × 10 ³	62
24/48	0.701/0.295	7,722 × 10 ³	177
32/60	0.5/0.246	12,300 × 10 ³	282

aerosols applied either by ground or aircraft indicate that for control of mosquitos in dense jungles an increase of 3 or more times the usual dosage per acre is required for effective control.

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Workshop Summary

Edward M. Fussell¹

The initial efforts of this workshop group on application were directed toward briefly describing the present technology related to application of pesticides. We discussed only those types of equipment and techniques that have been in use over the past few years. We considered two groups of equipment because two basic interest groups were represented: the forest entomology group and the mosquito control group.

For the forest insect work, we have fixed-wing aircraft ranging from single-engine equipment to DC7's, in addition to rotary-wing aircraft. All of these equipment systems are primarily based on liquid spray. The application rates for these systems in the United States are about 1 gallon of material per acre; this is total volume, not actual material. This figure varies somewhat in the other parts of the world: for example, in Canada the application rates are commonly 20 ounces per acre. In forest insect control, there is also a pretty wide variety of basic ground equipment, such as mist dust blowers, hydraulic sprayers, and backpacks. Obviously, use of ground equipment is limited to relatively small areas.

Equipment for mosquito control is a little more varied than that for forest insect control. It was necessary to categorize equipment, not only as aerial or ground types, but also as to suitability for adulticiding or larviciding. For mosquito larviciding, fixed-wing and rotary-wing aircraft are adapted for application of either liquid or dust formulations. Fixed-wing equipment for mosquito adulticiding is primarily limited to liquid dispersal systems. A few years ago, fogging with fixed-wing aircraft was a commonly used technique, especially in Florida. I believe it is not used as widely today. Larviciding with fixed-wing aircraft is principally the application of liquid or granular material. Ground equipment for larviciding--here again we use liquid or dry application--includes hydraulic sprayers, mist dust blowers, and backpacks. For adult mosquito control we have a variety of equipment. Mosquito abatement district in California are just coming around to adult control. The districts have concentrated principally on larval control in the past but now are looking to adult control through necessity.

Mosquito abatement districts in the Eastern and Southeastern United States have concentrated more heavily on adult control. Adult control equipment includes thermal foggers, cold foggers, mist dust blowers, and backpacks.

It was generally agreed that there is a real need for new equipment or for vast improvement in the presently available equipment. The development of insecticide dispersal equipment, for all practical purposes, started after World War II. Several different types of applicators were developed initially and not much change occurred for the next 20 or 25 years. Now we are beginning to realize that what was once considered adequate no longer meets our requirements. The relatively ineffective dispersal equipment used over the past years has resulted in a gross waste of insecticides and unnecessary contamination of the environment.

There is a need to determine median lethal doses for specific insects. We need additional information on the mode of action of insecticides. We need to know exactly how insecticides enter the insect. This is particularly true of aerosols. It is essential that we determine where the droplets impinge and how they gain entrance into the insect.

One of the most important things that could result from this conference is that we agree on the importance of the work on determining droplet size requirements and strongly support it. Although considerable work was done during the early forties on droplet size evaluation, only in recent years have we come to grips with the problem. Dr. Himel has been studying this problem for many years and I'm sure he will agree on the importance of droplet size. Achieving the proper droplet size could mean the difference between applying a quarter of an ounce of material per acre and applying a pound and a half per acre. There can be this much difference.

We feel that something should be done to determine the most efficient formulation for specific pesticides and pesticide delivery systems. It is time insecticide manufacturers and formulators started developing insecticides that fit a particular type of equipment or application. The old system of determining what is an ideal insecticide has been reversed. The emphasis on developing long-lasting insecticides has changed. Now, the point is not how long it lasts but how quickly it will

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break down. For the aerosols, the ideal insecticide could be one that would break down and become harmless a few hours after application. If you're depending on contact, as you would be with an aerosol, once the insecticide impinges on the target and performs its function, the insecticide is no longer of any use, and the sooner it breaks down the better. When put out in aerosol form many insecticides break down within a matter of hours, and this is a characteristic that can be used to great advantage. We don't wish to imply, however, that aerosols are the answer to all our problems, because there will always be a need for other types of insecticide application.

Something should be done to minimize loss of the insecticide to the target area. One of the most important things to keep in mind is that there is no way to control an aerosol so that it stops at a certain line. But, maybe there are ways to compensate for this, perhaps by manipulating concentrations and application rates. So that once the aerosol passes beyond that certain line the concentration of material, and the amount of material there, is no longer too significant. Also, when insecticides that break down rather rapidly are being used, loss beyond the target area is of less consequence. I believe we all agree that we're not on the verge of banning the use of pesticides. We're going to be dealing with these chemicals for decades.

There appears to be a need to clear up confusion in the use of terminology like "ultra low volume." Mr. Pierpont reported during the session that by EPA definition, ULV is the

application of less than half a gallon of total volume per acre without regard to insecticide concentration. Literally the definition is correct because the reference is only to volume. The problem here is that we were able to utilize ULV applications only because concentrations were increased, sometimes to near-technical-grade levels. For example, a few years ago we used malathion 6 percent as an adulticide for mosquito control. Now we use malathion 95 percent without dilution. Although the EPA definition may be useful to that agency it is likely to lead to further confusion for those engaged in the application of insecticides. It would be difficult indeed to refer to ULV without at least implying that the concentration of the insecticide had been increased, sometimes markedly, because as you decrease the volume you must compensate by increasing the concentration. It is obvious that we need more meaningful terminology. During his presentation yesterday Dr. Himel suggested the term Ultra Low Dosage. It certainly seems that ULD makes more sense than ULV. After all, we are primarily interested in the amount of insecticide that is applied to a given area and not so much in the application rate, except in special cases where specific dispersal rates would be required to achieve a desired effect or prevent undesirable effects.

It was brought to the attention of the group by Dr. Akesson that the World Health Organization has now substituted micrometer for micron and volume median diameter for mass median diameter.

Discussion

DR. TSCHIRLEY: You mentioned the need for new equipment or modification of existing equipment. What is the inference on this? Do you mean that new technology is needed for the development of the new equipment, or that the new technology is available, but it is simply economics that is holding it up?

COMMANDER FUSSELL: I am not sure that the technology is available. I think that what we are going to have to do, before we develop new equipment, is to determine what is needed. In the past, equipment was developed just to spray insecticides without regard to droplet size or anything of that nature. So I think that we first have to decide the optimum size for the target insect.

DR. TSCHIRLEY: When you are talking about this new equipment, are you talking about the spray distribution system or the vehicle that carries the distribution system as well?

COMMANDER FUSSELL: Well, I would be more concerned right now with the distribution system itself. The vehicle for that system is an entirely different thing, and I don't think it makes any difference whether it is ground equipment or aerial equipment.

MR. RANDALL: I noticed in the workshop that there seems to be a complete absence of reference to a standard. I think we should have a standard solution or a standard formulation for which all the work could be correlated.

So if you are talking of existing equipment or new equipment it should be carried out on a standard formulation.

COMMANDER FUSSELL: That was one of the comments made in the group yesterday, too. But I did not mention it because I knew it was going to come up in the assessment presentation. Everybody there agreed that there was a real need for some sort of a standardized assessment of spray droplets, because when you get into the field with your equipment you have no practical way to determine droplet size.

DR. LYON: Yesterday Dr. Akesson mentioned that he thought rotary atomizers were passé. Would he describe what he means by that? I wonder if that subject came up in the application workshop?

COMMANDER FUSSELL: It did come up, only briefly though. The comment that Dr. Akesson made was that on one particular model, where the specifications indicated that it produced droplets at a size of 10 microns, they actually observed droplets of 30 or 40 microns. They were not getting the droplet size that was advertised.

DR. ROBERTS: Dr. Akesson, do you have any comments to add to that?

DR. AKESSON: I don't believe that I said the rotary atomizers were passé. Rather, the point I was trying to make was that these devices, spinning at high speeds, are more subject to breakdown and are much more expensive than pressure nozzle systems. The drop-size spectra they produce is not significantly different from that obtained with the simpler pressure nozzles.

However, I would like to take this opportunity to take Commander Fussell to task. I got the impression yesterday that you felt the spray application equipment industry was not providing as much in the way of new equipment and application techniques as it should be. I would suggest that it isn't so much a matter of not having new equipment produced, as it is a lack of communication between many of our biologists who control our spray programs and the people who manufacture the equipment. In other words, the biologists request to equipment manufacturers may be mechanically illogical, while the machines that are being offered may appear to the biologists to be antiquated and impossible to use for the job to be done. Again, I would suggest that communication is the basic problem. As far as I can tell, there are no application machines on the market today that haven't been around, at least in basic design, for at least 25 years. However, in an

attempt to meet the sometimes nebulous demands of the biologist, the equipment manufacturer has produced some very fanciful devices, and all too frequently he also makes claims for these machines that strangely enough sound exactly like the requested performance.

Take, for example, the present enchantment with cold aerosols or cold foggers, particularly the ones that add ULV to the specifications. If you go into the literature and examine the work of Randall Latta, Alfred Yeomans and others of the early 1940's, you will find that the use of aerosols, both cold and thermal, was widely discussed, and extensive experimentation was carried out, the depth and quality of which has not been approached since then, with perhaps the exception of the biological-type research being done today at the USDA Gainesville Station.

However, I note that in a great deal of biological work, such as screening tests of various chemicals, and tests of the general results of each machine on adult or larvae control, basic parameters of weather, machine operation, and sometimes proper biological statistics are omitted or ignored. These are mighty poor examples of research, and to claim to report on population control without specifying or identifying the many variables involved—physical, chemical and biological—is too frequently only adding confusion and wasting good journal space.

Obviously this state of things is easily described, but much more difficult to do anything about. However, I would again suggest that the biological and physical science interface—the relationship between the insect population effects and the chemical, the mode of action, type of application, application machine, geographical terrain, and meteorological parameters—should be considered and carefully evaluated if sound research on such things as vector control, forest insect control, and of course agricultural economic insect control, is being attempted.

This total approach is being called systems control or integrated control, and of course cultural, sanitation, and biological control, including predator-parasite functions, must be included.

Another facet of our science research interface is the problem of communication in mathematical terminology. It is, I realize, very simplistic for me as a physical scientist, to point at the biologist and say that what he needs is more number-oriented data—statistics, computer analysis, modeling studies, and in general, a tightening up of data analysis. We must recognize that the computer, for example, is a very powerful tool and no amount of derogatory stories about its inhumanity

and stupidity, especially in relation to our charge accounts with a large department store, is going to detract from its tremendous capabilities in rationalizing the type of research and data analysis that we all need in our work.

I hope that I am not minimizing the tremendous efforts and very valuable work being done by many of the biological scientists involved in pest control work. Rather, I would hope that my speaking out here today will help to open a route of information exchange and research collaboration which will benefit us all, both as researchers and as citizens.

The work associated with particle size, whether of spray or dry particles, has always been significant in relation to pest control. Back in the DDT days, a lot of effort was devoted to determining the size of droplet that would do the best, most efficient job for specific insect control. Unfortunately, the researchers then got to the same place our people have reached today, the only difference being the chemicals used. Basically, the aerosol size drops that Drs. Himmel, Weidhaas, Mount, and others have found to be most effective in controlled application studies, both laboratory and field, are not (1) easily produced, or (2) easily counted and sized, or (3) easily used under the conditions of practical application work. Is this not, in part at least, a lack of communication between physical and biological scientists? The physical scientist perhaps errs in his insistence on using easily managed, large-drop-size, rapidly falling sprays, but equally inconsiderate is the biological scientist's insistence that if his controlled tests prove certain facts, extrapolation to field applications should be automatically and easily accomplished if the equipment people would simply buckle down and do their end of the job.

I submit to the biologists that this situation is extremely unproductive and I would beg of you to give greater consideration to such means of approach as integrated or systems control, not after your decisions as to rates, drop size, and insect response work has all been done, but right from the time of the first chemical screening work which shows that a chemical formulation has promise for a particular job. I shouldn't expect that miracles are going to suddenly occur from such integration of research effort, but we certainly have little to lose and perhaps much to be gained by giving it a try.

COMMANDER FUSSELL: Thank you Dr. Akesson.

I don't think there was any intent to imply that the study of aerosols only started in the last decade. We would not want to discredit Yeomans or Latta or any others. Many assumptions have been made regarding aerosols, particle size, impingement and things of this sort, and I think that some of these assumptions are without basis. So the time has come to update this information and use that as a basis.

DR. KIETHLY: It seems to me we have studied the literature quite a lot on what people have done, but how do we put it to use?

COMMANDER FUSSELL: Something should be done. It might be something for government to consider or it might be something for industry or a combination of both to consider.

DR. TSCHIRLEY: I would like to return to my original question and ask Dr. Akesson, in light of this discussion, whether or not the technology is available now to do what we want with these spray systems, or do we need more research to define this, or is there a need to make the equipment that will produce what we want?

DR. AKESSON: I think that the technology is there, but I do believe that the key to this is the need to get the equipment and the biological requirements lined up and correlated. And again I would say, yes, the technology is there, it is a development process. I work in agricultural engineering, and where does our information come from? We get it from "space" people, mechanical engineers, civil engineers, sanitary engineers and others, and apply it to agriculture. There you have a tremendous background and source of technology. If we can find the information we need in these areas and bring it to bear, this is the general plan that we follow. I think that the technology is available but we do need that specific relationship.

DR. LILIJDAHL: I do not see how you can say that we have the technology available. At least one important part of the technology required, if droplet size is important, is the ability to produce--in practical quantities and in practical situations--reasonably uniform spray droplets of a desired size. Now, as far as I know, there is only one process available for doing that in a practical situation in the field. That is the one that we have developed, that Dallas has worked on at College Station, and that I am working on again now. That has three important limitations. First, it will not go below 75 microns; secondly, it is not good if you have suspended materials in wettable powders; and third, nobody knows for

sure if it will work in high speed air streams. Chances are it will not. Consequently we do not have a method of producing spray droplets below 75 or maybe 50 microns of reasonable uniformity, that is, something that has a coefficient of variation of, say, less than 20 percent or even less than 50 percent. Most of the air atomizing nozzles that we use for fine sprays are terrible, when you consider their coefficients of variation. I do not see how we can consider those to be uniform sprays. When we are releasing these very fine sprays, who knows how many drops we are producing that are less than 2 microns -- drops that we can not even measure. I do not think we have the technology available.

DR. AKESSON: The problem that Lou is bringing out, and again I agree with 100 percent, is that of trying to produce the tools that we need to do the research. We do not have those, let alone the practical type things that we could take into the field. Identification of small particles is greatly improved. We are doing quite a bit of work with a scanning electron microscope now, and we can identify sub-micron particles now, but it is not easy.

DR. LILIJDAHL: I thought that Fred Tschirley was referring to whether the information and technology was available to design and actually mass-produce such a machine. I do not think we have that technology.

DR. AKESSON: We have the first-step or first-generation equipment, as it were, to do the research work. Agreed, we can not go into the field with such a machine at this date.

MR. RANDALL: Can I ask a question at this point? Are you referring to droplet generators?

DR. AKESSON: Yes, both as laboratory types and field types.

DR. LILIJDAHL: Now I am not talking about laboratory generators. I was talking about practical field equipment.

MR. RANDALL: There is one point I would like to bring to the attention of the group here and I am sure, Ed, you are probably familiar with it. Laboratory droplet generators have been produced at Suffield for the Defense Research Board, and publications describing this equipment are available. As for droplet generators out in the field, the problem, I feel is that there are too many of them and there is no correlation between one machine and the next one, mainly because of the lack of a standard solution, which was a DDT-Velsicol-fuel oil combination. Of course the DDT was the standard insecticide and we

compared everything to that particular insecticide; the aromatic fuel oil formulation was our standard liquid, so that we could compare all new formulations against this standard. In this way we had some correlation between the various years that we did our work. But if we did one thing at this meeting, it would be to come up with a standard solution, so that everybody would use that one formulation or one liquid; then the next time we meet we would at least have that one thing in common. The data could be interpreted by everybody. Now even if the work was done with droplet generators, or done in the field, we would have some means of comparing our work or data.

DR. MAKSYMCIUK: I would like to add to Randall's comment on the need to develop standard formulations or solutions in order to compare our laboratory and field results. At the same time, we also need to standardize our methodology. Despite the fact that some existing methods for determining spray atomization and assessing spray deposit are comparable, additional standardization and common acceptance of methods are needed internationally.

I would like to comment on the three areas related to the aerial application spray equipment:

1. *Coverage: surface area of foliage vs. surface area of land* -- The amount of pesticide delivered by various kinds of spray equipment is currently expressed per acre of land area, disregarding the variable amount of the surface area of foliage per acre. For example: how many acres of surface area of foliage are there in an acre of land? We ought to consider horizontal and vertical variation in vegetation (cabbage field, Douglas-fir forest, oak forest, etc.). Therefore, it would be more realistic to express the coverage in terms of area of foliage (gpa, or amount of pesticide per unit surface area of foliage) instead of as traditionally expressed per unit surface area of land (gpa, pounds per acre, etc.). This concept, if used in the field, will provide more reliable determinations and comparisons of field dosages and will result in better reproducibility of insect operational control programs.

2. *Microbial insecticides* -- We underestimated in this workshop the importance and need of spray equipment for delivering microbial insecticides. These biological insecticides (bacteria, viruses) are applied as suspensions whereas most chemicals insecticides are applied as solutions. The major problem is that suspended insect pathogens settle out, in spray formulation mixing equipment, in aircraft tanks, and in spray

delivery systems. An acute problem in the storage of microbial suspensions is the sedimentation and agglomeration of particles. This leads to variable delivery of pathogen concentrations, with erratic foliage coverage, and in turn, variable and unreproducible results in insect mortality by place and time.

We eliminated this problem by working as a team with engineers in conceiving, designing, and fabricating special spray mixing and loading equipment and an aircraft spray system. This equipment provides for the continuous recirculation of spray formulation in the spray tanks and spray booms (on the ground or in flight) without injury to the pathogens either by mechanical sources or heat. Developed technology is being applied in the field research experiments. Hopefully, it will be transferred to the operational use as soon as microbial insecticides can be used operationally.

3. *Aerial application of pesticides* -- We have difficult problems in aerial application of pesticides in forestry mainly because we cannot control variable meteorological and topographic conditions. Therefore, the spray equipment must have versatility for obtaining the desired spray atomization (drop size spectra) and application rates (volumes of liquids) for achieving specific pest control objectives safely and effectively under a wide range of physical and biological field conditions.

DR. TSCHIRLEY: Formulations were mentioned as a need, too, in terms of further research. Two questions on this: What is the level of effort in developing new formulations now and was there any discussion of the group's feelings as to whether this was the responsibility of the public or the private sector?

COMMANDER FUSSELL: We really didn't delve deeply into that part of it. It is difficult to say at this point who will be responsible. The government probably does most of the research, but the people from Dow, MGK, Chemagro, etc., might argue about that since they do a tremendous amount of research themselves. This future research might not be assigned to any particular group, but it is work that should be done, to develop formulations, different concentrations, or different carriers. We have obtained some very interesting results with some of our work with emulsions. And this sort of thing should be explored more fully.

DR. ROBERTS: It seems to me that we have been talking about the need for standards of techniques and procedures but we have not pointed a finger at who is going to organize

this. We should organize some sort of governing body now so that we can assign committees and begin the task of defining standards and techniques. Otherwise, we will return to our laboratories, and next year will come back to this workshop and the same criticism and comments will be made about the lack of standards or means of comparing data. So let us organize ourselves here and now so we can start on this problem of standardizing our methods and techniques.

DR. MAKSYMCIUK: I understand EPA has a committee on standardization and nomenclature pertaining to pesticides. I talked to the head man just a few weeks ago. At a meeting somewhere in Philadelphia, several engineers walked in, and they were feeling uneasy because they couldn't participate. But the chairman asked the engineers to form a committee and assigned them the task of working on the standardization of methodology and nomenclature. I don't know whether a report transpired from that or not. Perhaps some of the engineers here now know what their colleagues are doing.

DR. ROBERTS: Are we talking about the same thing, Bohdan? I am talking about an internal organization composed of the people that are doing the work. I understand that there has to be some federal regulations established by EPA.

DR. MAKSYMCIUK: Once such procedures are accepted by EPA, then they are mandatory to use. It is very important that we participate on that committee so that the nomenclature and standardization are the kind that we would like. I urge that we pursue this matter and get in touch with them, then if the need arises we provide sizeable input. It would be a good idea also to solicit such input, maybe in an advisory capacity, from the Canadians and anybody else who would like to contribute.

DR. ROBERTS: Dr. Tschirley, I would like to hear your comments on that. Do you have any help or information on this matter?

DR. TSCHIRLEY: What the gentleman refers to I think is a current effort by ASTM, The American Society for Testing Materials. They have had several meetings now, with some difference of opinion as to just what the stimulus of this was. But, presumably, what they are to come up with at some point in the future is a standardization methodology for information that EPA needs in the pesticide registration process. Now the nomenclature I think is a part of this, and this is something that would come fairly easy. But

other than that, it is the methodology of the test that is required for the registration of the materials that they are looking at, insofar as I know anyway, rather than any methodology that is involved in the development of the equipment for delivering pesticides. According to the new pesticide legislation, this does not cover the registration of the application equipment itself. Of devices for pest control, yes, and of the pesticides themselves, yes, but not the equipment for delivering it. So what you suggest, Richard, that a group get together to standardize some of the parameters that you have to deal with day after day, is an excellent suggestion.

MR. PIERPONT: What Dr. Tschirley just said is correct, and I think that Dr. Roberts' suggestion is a good one. At the present time we are putting together guidelines for

the registration of pesticides in the United States. One part of that is the Appendix which will include all of the test methods acceptable for the development of these pesticides. This is where your input would be very greatly appreciated.

DR. ROBERTS: We have a golden opportunity here to "write our own book" so to speak. But who is going to take the initiative and will organize this group? This is really not my field, so I am going to pass the buck.

MR. RANDALL: I would like to take this golden opportunity to pass the buck a little further. I think the group that works in forestry should handle the requirements for their area and the group that does the mosquito work should handle that particular type of work, so at least the experts would be in their own field.

The Micrometeorology and Physics of Spray Particle Behavior

Harrison E. Cramer¹ Douglas G. Boyle²

Abstract--During 30 years of experimental programs at Dugway Proving Ground, techniques were developed for computer modeling of spray cloud behavior. Atmospheric transport and diffusion processes within forest canopies are generally quite different from those in open terrain, as illustrated by normalized vertical profiles of windspeed and temperature. Deposition of aerial sprays on vegetation or insects is apparently the result of many different processes that are not well understood. Some data on canopy penetration has been gathered in tests using Zectran.

This discussion summarizes the techniques used to support experimental spray programs at Dugway Proving Ground. The time span is 30 years. The spray programs themselves were designed primarily to evaluate specific military systems or items of developmental hardware. For that reason, viewed historically, they show no continuity of objectives. Continuity is provided, however, by the recurrence of the same unknowns. It is reflected also in the evolution of improved sensors, assay and analysis techniques and, since the late 1950's, increased reliance on computer modeling of spray cloud behavior. The current approach to modeling is the central theme of this paper. In the development of the computational schemes presented, the objective has been and continues to be a more useful alignment between theory and field experiment in the physical description of aerosol and droplet behavior. Atmospheric transport and diffusion processes within a forest canopy are discussed in a later section. The concluding section presents the scant data generated (through 1972) under the cooperative agreement between Army and Forest Service investigators.

GENERALIZED MODEL CONCEPT

The employment of mathematical prediction models has proved mandatory in quantifying the atmospheric behavior of military systems, since many such systems cannot be tested. Use of prediction models is also essential in the design of field trials and in the interpretation of field measurements. The concept of generalized concentration-dosage prediction models was first stated by Milly (1958) who pointed out the necessity for separating the effect of source factors, meteorological factors, and site factors in the analysis and generalization of chemical and biological field test data. This concept has been broadened and implemented in work at Deseret Test Center (Cramer and others, 1964; 1972) and is the keystone of the model formulas for aerial spray releases given below. The generalized models are intended to be universally applicable, by suitable selection of source and meteorological input parameter values, to all dissemination systems, to all environmental regimes, and to all requirements. These requirements typically include the design of field tests, assessment of the results of field measurements, extrapolation of these results to field operations, development of dissemination systems, and hazard-safety analyses, among others.

The basic generalized model format is a mass continuity equation that in principle provides a complete description of the trajectory and properties of an aerosol or heavy particulate

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cloud, from the time of cloud stabilization (approximate equilibrium with ambient conditions immediately following dissemination), until the cloud has passed beyond the maximum downwind travel distance of interest. The terms included in the generalized model must therefore specify the direction and rate of downwind cloud travel; the alongwind, crosswind and vertical cloud dimensions as functions of travel time and distance; the distribution of material within the cloud as a function of time and distance; and losses of material through decay or removal by such agencies as hydrometeors, gravitational settling, and other surfaces. The generalized model must also provide for the effects of variations in the chemical and physical properties of the material contained in the stabilized cloud; in the mode of release and source emission time; and in the meteorological, terrain, and vegetative factors.

The Deseret Test Center model equations are similar in form to the Gaussian diffusion model formulas first developed by A. G. Sutton (1953) and later extended by Pasquill (1962) and others. A Cartesian coordinate system is employed, with the origin placed at ground level directly below the source. The x axis is along the direction of downwind cloud travel, the y axis is normal to the alongwind axis in the plane of the horizon, and the z axis is directed along the vertical. The auxiliary equations for the lateral, vertical and alongwind cloud dimensions are expressed as simple power laws and contain direct meteorological predictors. Other distribution functions, coordinate systems, cloud expansion laws and meteorological predictors can be substituted in the models. In addition to using direct meteorological predictors, the Deseret Test Center models also provide for the inclusion of mesoscale meteorological factors which control atmospheric diffusion, transport, and depletion processes for cloud travel distances in excess of 1 or 2 kilometers. The mesoscale factors most important in determining the dimensions or aerosol clouds at distances greater than a few kilometers downwind from the point of release are the depth of the surface mixing layer and the vertical shear of windspeed and azimuth wind direction in

this layer. It follows that a choice of expressions used in the model to account for the effects of microscale processes, particularly small-scale turbulent mixing, is frequently not of critical importance. Other important innovations in the Deseret Test Center models include specific provisions for the effects of initial cloud size and source emission time on downwind concentration-dosage patterns.

It should be recognized that the generalized model formulas are inherently interim or state of the art expressions reflecting the best available knowledge. Provision has been made for their refinement and improvement as new information becomes available. In many instances, the appropriate source and meteorological information is fragmentary or almost completely lacking. Because of inadequacies in existing measurements, the amount of rigorous model validation that has been possible to date is disappointingly small. However, the experience in model validation has demonstrated that the overall conceptual framework is sound and that the accuracy of model predictions is limited principally by the accuracy and adequacy of the source and meteorological inputs.

Generalized Model Formulas for Aerial Spray Releases

In aerial spray releases, the release of material to the atmosphere is completed almost instantly as the spray cloud generally reaches an approximate equilibrium with the ambient air flow within seconds. This approximate equilibrium is referred to as cloud stabilization and the source inputs used in the model refer to the properties of the spray cloud immediately after it has stabilized. These properties include the dimensions of the stabilized cloud, chemical species contained in the cloud, total amount of each species, size distributions and densities of particulates or droplets, and spatial distribution of each species within the stabilized cloud.

In the generalized concentration model for aerial spray releases, the concentration of airborne spray material downwind from the point of cloud stabilization is given by the product of five terms:

$$\chi(x,y,z,t) = (\text{Peak Concentration Term})(\text{Alongwind Term})(\text{Edge Effects Term}) \\ (\text{Vertical Term})(\text{Depletion Term})$$

The Peak Concentration Term refers to the concentration at the center of the cloud ($x = \bar{u}t$, $y = 0$, $z = H$) and is defined by the expression

$$\frac{Q_L}{2\pi \sigma_x \sigma_z}$$

where

$\bar{u}$ = mean windspeed

H = height of the center of the stabilized cloud or effective release height

Q_L = total quantity of spray material released per unit length of the release line

σ_x = standard deviation of the alongwind concentration distribution

σ_z = standard deviation of the vertical concentration distribution

The remaining four terms, which are all dimensionless, are defined as follows:

$$\text{Alongwind Term} = \exp \left[-\frac{1}{2} \left(\frac{x - \bar{u}t}{\sigma_x} \right)^2 \right]$$

$$\text{Edge Effects Term} = \left\{ \frac{1}{2} \left[\operatorname{erf} \left(\frac{L/2+y}{\sqrt{2} \sigma_y} \right) + \operatorname{erf} \left(\frac{L/2-y}{\sqrt{2} \sigma_y} \right) \right] \right\}$$

$$\text{Vertical Term} = \left\{ \exp \left[-\frac{1}{2} \left(\frac{H - (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{2H_m - H + (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] \right\}$$

where

V_s = gravitational settling velocity

H_m = depth of the surface mixing layer

Depletion Term (Precipitation Scavenging)

$$= \exp \left[-\Lambda \left(\frac{x}{\bar{u}} - t' \right) \right]$$

where

Λ = fraction of material by weight removed by scavenging per unit time

t' = time after cloud stabilization that precipitation begins

$$\text{Depletion Term (Decay)} = \exp (-kt)$$

$$= \exp \left(-k \frac{x}{\bar{u}} \right)$$

where

k = decay coefficient

The total weight of heavy particulate or droplets deposited per unit surface area (contamination density) is defined by the expression

$$\omega_L = \frac{f_i Q_L}{\sqrt{2\pi}} \left\{ \frac{1}{2} \left[\operatorname{erf} \left(\frac{L/2+y}{\sqrt{2} \sigma_y} \right) + \operatorname{erf} \left(\frac{L/2-y}{\sqrt{2} \sigma_y} \right) \right] \right\} \left\{ \exp \left[-k \frac{x}{\bar{u}} \right] \right\} \{ M + N \}$$

where

$$M = \left\{ \frac{\beta H + [V_s (x + x_z) / \bar{u}] [1 - \beta x / (x + x_z)]}{\sigma_z (x + x_z)} \right\} \left\{ \exp \left[-\frac{1}{2} \left(\frac{H - (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] \right\}$$

$$N = \left\{ \frac{\beta (2H_m - H) - [V_s (x + x_z) / \bar{u}] \left[1 - (\beta x / (x + x_z)) \right]}{\sigma_z (x + x_z)} \right\} \left\{ \exp \left[- \frac{1}{2} \left(\frac{2H_m - H + (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] \right\}$$

In the above expressions for contamination density,

f_i = fraction by weight of heavy particulates or droplets with gravitational settling velocity V_s

β = vertical diffusion coefficient of the order of unity

x_y = vertical virtual distance

The auxiliary model formulas used to define the standard deviations of the concentration distribution (σ_x , σ_y , σ_z)—which contain the turbulent intensities, diffusion coefficients, wind velocity, and other meteorological parameters—will not be presented here. A complete description of these formulas may be found in the report prepared for Deseret Test Center by Cramer and others (1972).

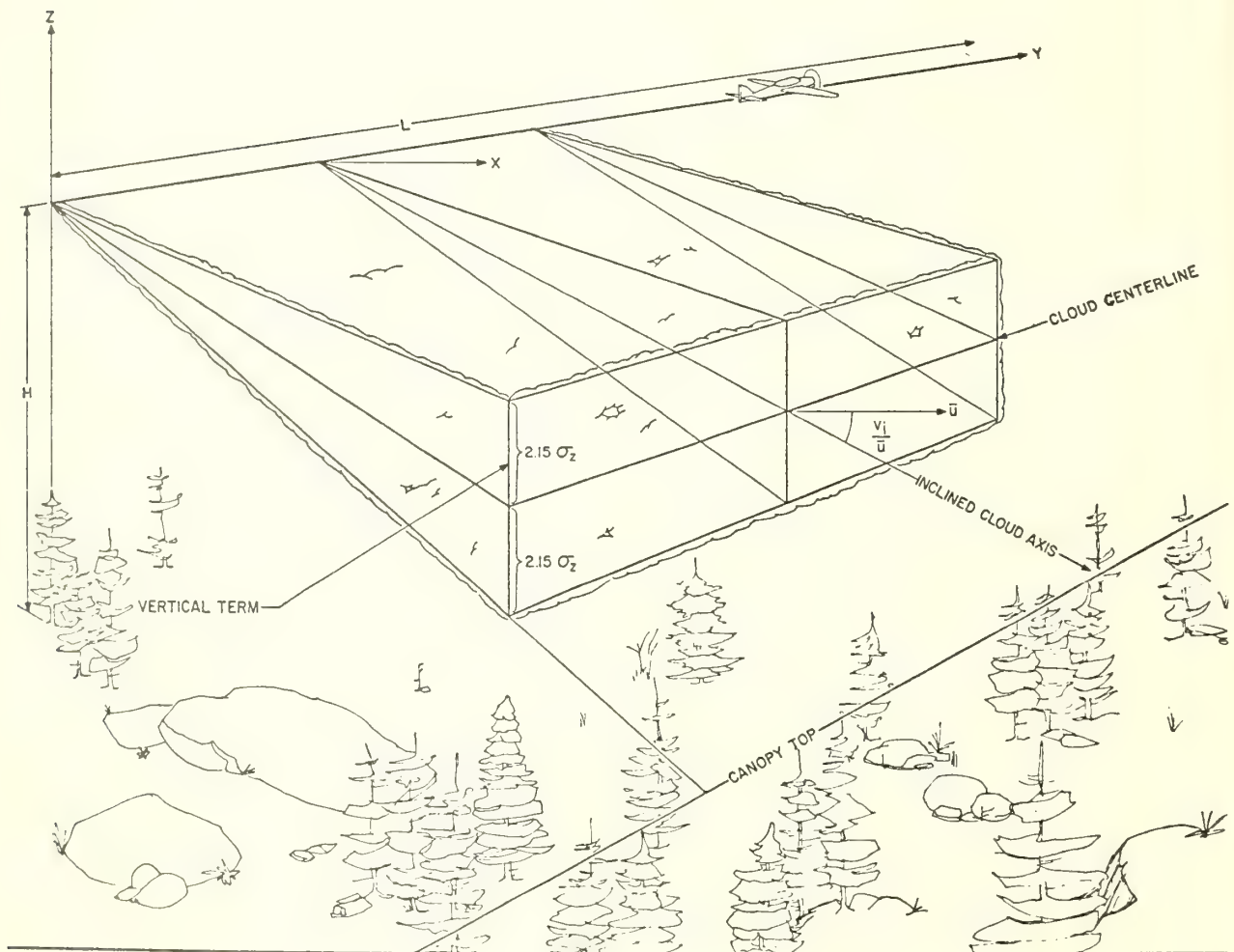


FIGURE 1. Schematic diagram of above-canopy line release model.

The aerial spray model just outlined was developed principally for use in open terrain and must be modified before it can be used to predict concentrations or contamination densities within forest canopies. As the model stands, it can very likely be employed to calculate spray concentrations and contamination densities at the top of a forest canopy resulting from aerial line source releases. The schematic diagram (fig. 1) shows the spread of a heavy particulate or droplet cloud from a line source release above a forest canopy. The features in the diagram refer to some of the more important model parameters. The inclination of the alongwind axis of the cloud centerline at an angle $v_i/\bar{u}$ to the horizontal (where v_i is the gravitational settling velocity of a class or heavy particles or droplets and $\bar{u}$ is the mean windspeed) shows the ballistic treatment of gravitational settling in the model. The growth of the cloud by turbulent mixing takes place about this inclined axis rather than about a horizontal axis, as in the case of a vapor or gas cloud.

The vertical term indicates the relationship between the vertical dimensions of the cloud and the standard deviation of the vertical concentration distribution. Although it is not shown in figure 1, the edge effects term accounts for the dilution of the cloud that occurs at the crosswind extremities (end points of the release line) produced by the entrainment and mixing of ambient air.

Examples are given (figs. 2, 3) of calculations of the total deposition of spray material, for selected drop sizes (density = 1.0), per unit surface area, at a height of 50 meters below the effective release height. This surface can be assumed to represent the top of a continuous forest canopy. When the mean windspeed is 5 m sec⁻¹, as shown in figure 2, the total deposition is approximately the same for all drops less than 100 microns in diameter. At low mean windspeeds, as shown in figure 3, the total deposition is approximately the same for all drops less than 40 microns in diameter.

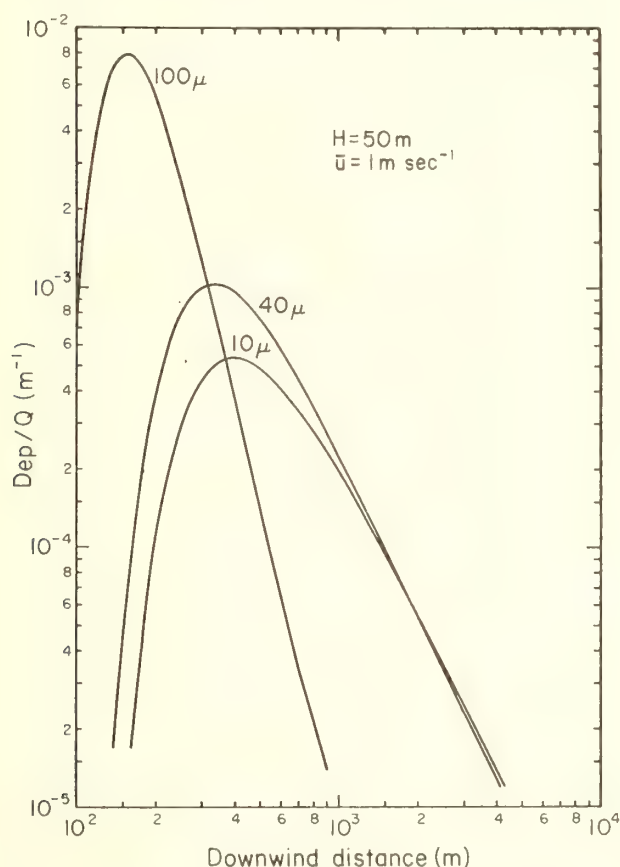


FIGURE 2. Total surface deposition from elevated crosswind line releases, at a height of 50 meters, for a mean windspeed of 5 meters per second for selected drop sizes.

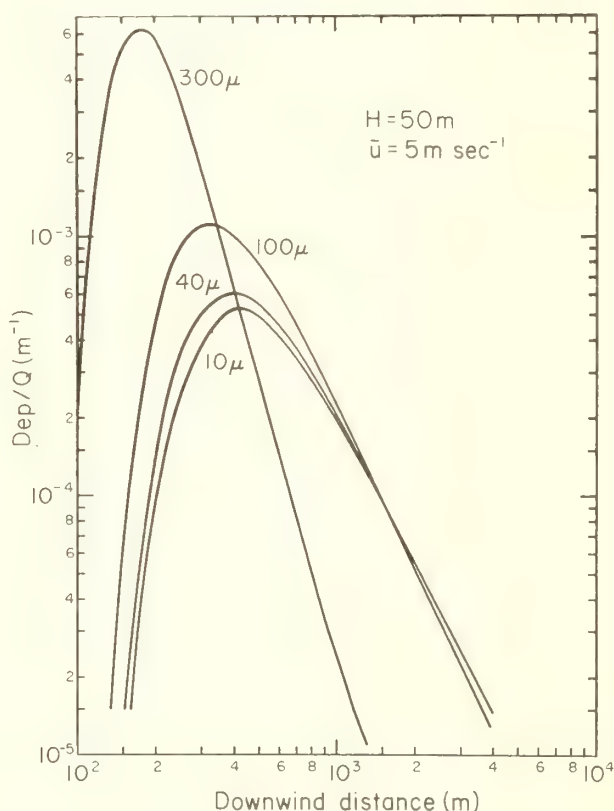


FIGURE 3. Total surface deposition from elevated crosswind line release, at a height of 50 meters, for a mean windspeed of 1 meter per second for selected drop sizes.

Atmospheric transport and diffusion processes within forest canopies are generally quite different from those in open terrain. In dense canopies, the meteorological structure is only very weakly coupled with the above-canopy meteorological structure. The wind and temperature fields that control below-canopy transport and diffusion consequently differ significantly from those that apply above open terrain in the absence of a canopy. The vertical profiles of mean windspeed and air temperature below the top of a forest canopy are of special interest. Normalized profiles of windspeed between ground level and the top of selected canopies (fig. 4) were reported by Fritschen and others (1970). We are interested primarily in the normalized profiles in figure 4 for the Douglas-fir forest, dense conifer stand, and moderately dense conifer stand. The relevant features of these profiles are:

- In the upper third of the canopy, there is a sharp decrease in windspeed from the above-canopy speed
- In the lower two-thirds of the canopy, the windspeed is almost constant with height, and is approximately one-quarter to one-third the value of the windspeed at the top of the canopy

An additional fact to be kept in mind is that the windspeed in the undisturbed air flow above the canopy is approximately twice the windspeed at the top of the canopy. This level of undisturbed flow is found at an equivalent canopy height above the top of the canopy. It follows that windspeeds in the lowest two-thirds of dense forest canopies will range from about 5 to 10 percent of the windspeed in the undisturbed flow above the top of the canopy. Below-canopy transport speeds in dense forest canopies therefore are generally of the order of 0.5 meters per second (1 mile per hour).

Typical profiles of the height variations in temperature that occur between the air layer above the top of the canopy and the ground surface below the canopy are shown in figure 5. The shape of these profiles is principally determined by the radiational cooling or heating of the top of the canopy. In fair weather, the top of the canopy is warmed by solar insolation during daylight hours. At night, the top of the canopy cools down because of radiational heat losses to the air layers above the canopy. The temperature in the lower part of the canopy tends to remain unchanged. The result is the production of thermally-stable layers (temperature is constant or increases

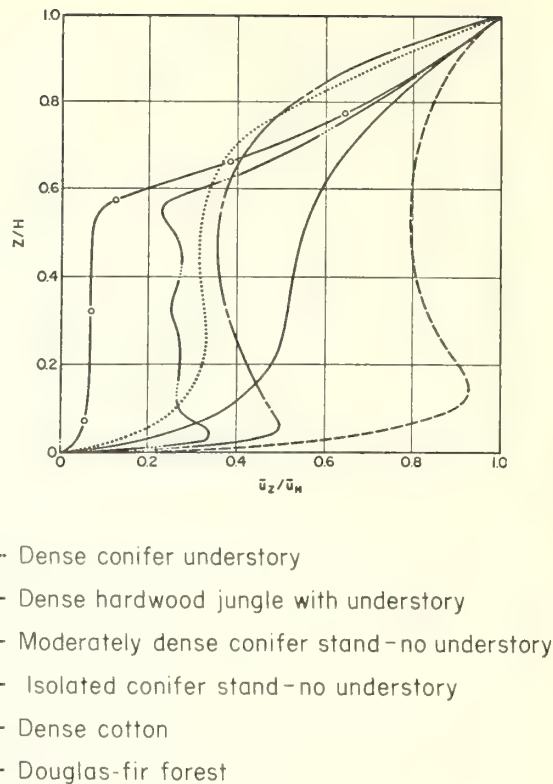


FIGURE 4. Comparison of normalized wind profiles of various vegetative canopies where Z is height above the ground, H is the height of the top of the canopy, and $\bar{u}$ is the windspeed. (From Fritschen and others, 1970)

with height) above and just below the top of the canopy at night and just below the top of the canopy during the day. As shown in figure 5, the air layer above the top of the canopy is thermally unstable (temperature decreases with height) during the day. On overcast days and nights, the temperature tends to decrease with height throughout the canopy and in the air layers above the canopy. A similar condition of thermal instability also occurs in fair weather during the early morning, late afternoon, or early evening. This condition is transient, and typically lasts for an hour or so during the changeover from day to day. The presence of thermally-stable layers is unfavorable for the diffusion of light particulates or aerosols containing small droplets. These materials are not able to penetrate thermally-stable layers, except as a consequence of gravitational settling which is generally insignificant for particles or droplets with diameters of from 10 to 20 microns or less. The practical significance of this phenomenon is that small

droplet aerial sprays released above dense forest canopies will have difficulty in penetrating and diffusing within the canopies except during the brief fair-weather change-over periods in the early morning or late afternoon, or during overcast conditions. If the spraying is performed with a helicopter that hovers at a low altitude above the top of a dense canopy, the downwash from the rotors may drive the spray material into the below-canopy region.

Another feature of below-canopy meteorological structure of interest is that the turbulent intensities tend to be quite large compared to typical values above open terrain. Turbulent intensity is defined as the ratio of the root-mean-square of the fluctuations of wind velocity about the mean velocity to the mean velocity. Typical values of this ratio above open terrain approximate 0.10. Beneath forest canopies, the ratio is approximately 1.0. The explanation is that the presence of the low wind velocities typical of below-canopy regimes and large fluctuations in wind velocity produced by air flow around obstacles lead to high values of the ratio defining the intensity of turbulence. Because the intensity

of turbulence is a good index of turbulent mixing or diffusion, this means that the diffusion processes below forest canopies are very effective in spreading light particulates or small droplets throughout the below-canopy region. It must be pointed out, however, that horizontal wind transport of airborne material is severely restricted by the low transport speeds. Also, because almost all canopies are open to the sky in selected location, entry and exit of airborne material is most likely to occur through these openings which act as natural chimneys. Much of this type of vertical transport of material occurs as the result of dynamic forces produced by the flow of air above the undulating surface presented by the top of the canopy. When the above-canopy windspeeds are of the order of 10 miles per hour, the below-canopy residence time of light particulates or small droplets is less than 1 hour, unless they are deposited firmly on vegetative or other surfaces prior to that time. This short residence time is principally caused by the rapid exit of material from the canopy in vertical air currents that form in the natural chimneys afforded by clearings or openings in the top of the canopy.

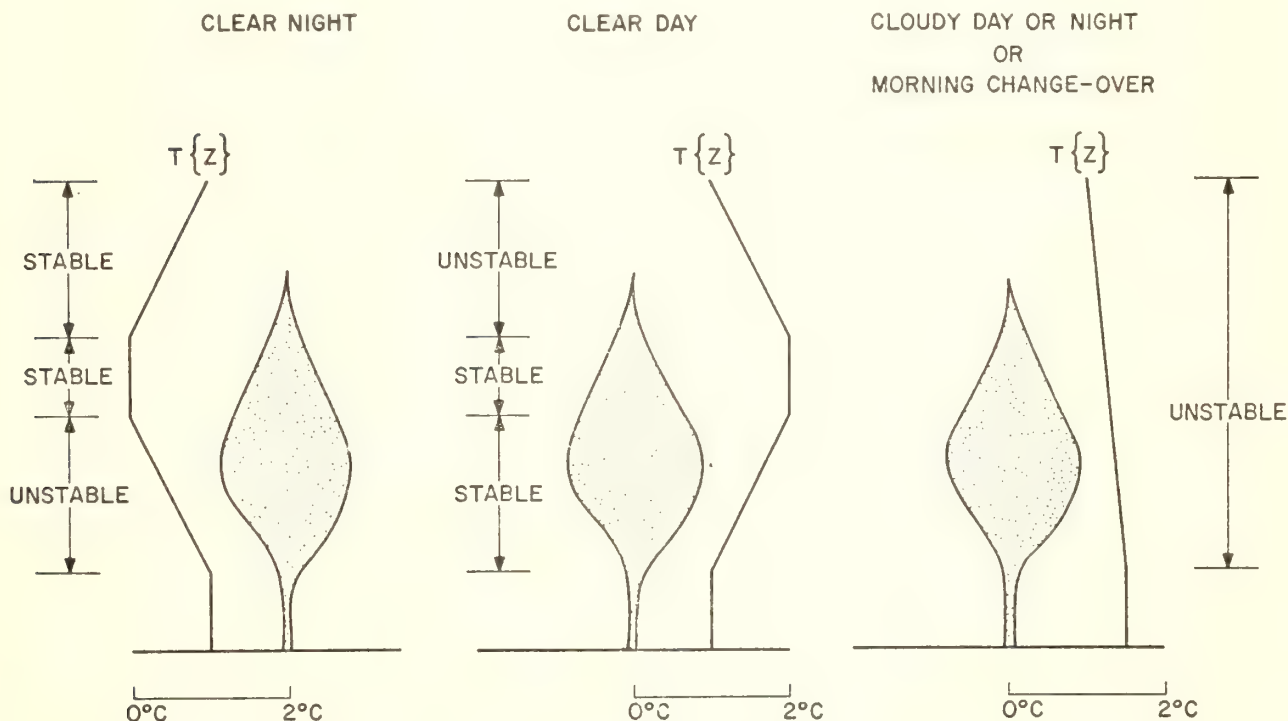


FIGURE 5. Vertical temperature profiles ($T\{z\}$) above and below a forest canopy. Thermally stable layers prevent turbulent mixing.

Deposition of aerial sprays on vegetation or insects appears to occur as the result of a number of different processes. Current understanding of the physics of some of these processes is severely limited. Also, the efficiency of the processes appears to vary with a number of meteorological, vegetative, and other factors. Four basic categories of deposition processes may be identified:

- Gravitational settling
- Inertial impaction
- Turbulent deposition or impaction
- Other processes such as electrostatic attraction, adhesion, and absorption

Gravitational settling would appear to be the dominant process leading to the deposition of heavy aerosols and possibly, under calm air conditions, may apply to light aerosols as well. The time required for spherical particles or droplets of unit density to fall through vertical distances of 10 meters

and 50 meters is shown (fig. 6) as a function of droplet diameter. Note that the fall times for 20-micron droplets are of the order of 10^3 seconds, whereas the fall times for 100-micron droplets are of the order of 10^2 seconds.

The inertial impaction efficiency E is shown (fig. 7) as a function of the inertial impaction parameter K for various target shapes. The theoretical basis of inertial impaction contains a number of listing assumptions, one of which is the existence of laminar flow. Within forest canopies, this assumption may be satisfied only under very special conditions, if at all. Figure 8, a simplified version of figure 7, shows an envelope of the values of the inertial impaction efficiency versus the parameter K for circular cylinders as the index ϕ for the Reynolds number of the cylinders varies over a wide range. Cylindrical shapes are assumed to be representative of small branches, pine needles, the spruce budworm and other insects that are targets for some aerial spray application. The graphs (figs. 9, 10) show the range of minimum droplet diameters (assuming unit density of the droplets) required to achieve inertial impaction efficiencies of 0.5 and 0.8 on cylindrical targets when the

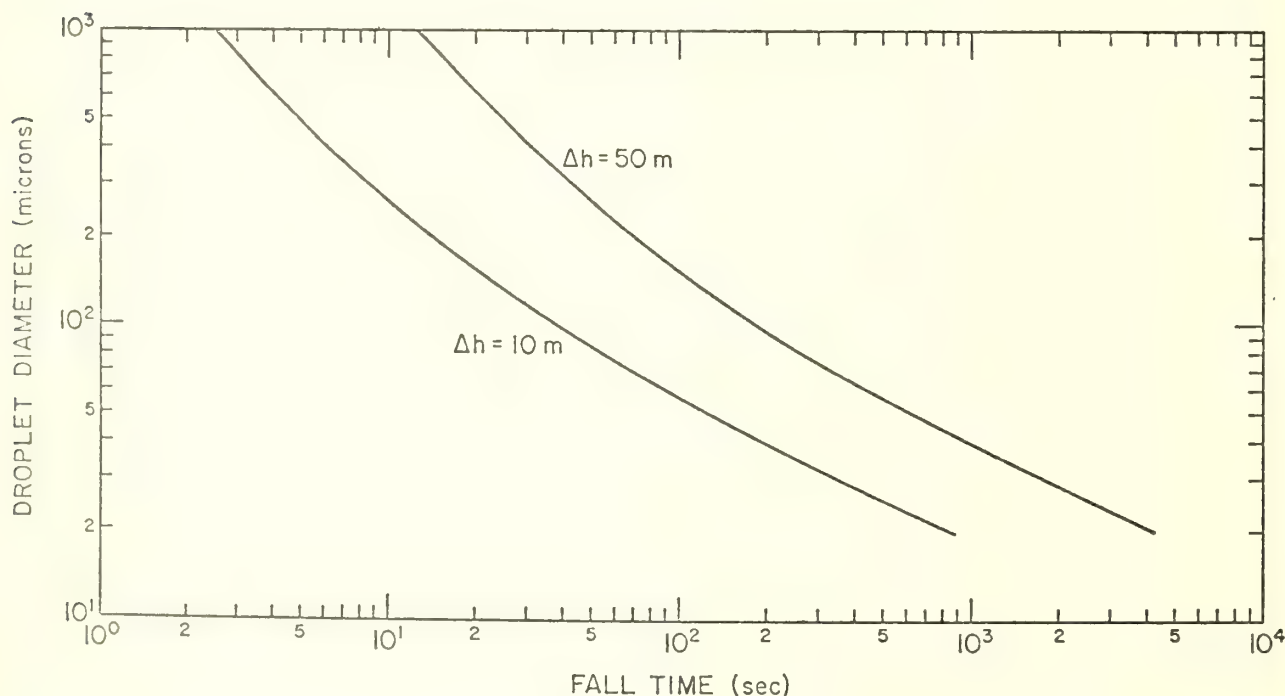


FIGURE 6. Time in seconds required for various-size drops of unit density to fall 50 meters and 10 meters.

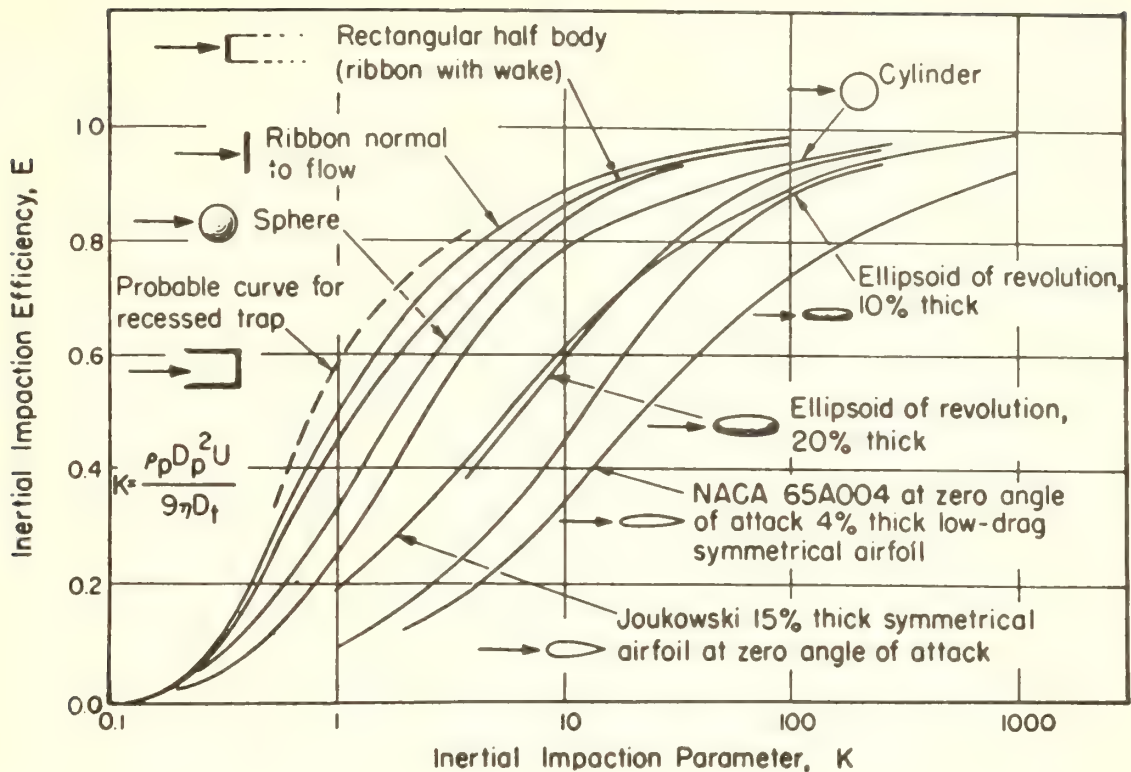


FIGURE 7. Inertial impaction efficiency E as a function of inertial impaction parameter K for a number of different target shapes. (From Golovin and Putnam 1962)

target diameter varies from 0.1 to 0.5 centimeters. The graphs have been constructed by solving the formula for the inertial impaction parameter K shown at the lower left of figure 7 and marking off the regions in which the inertial impaction efficiency E is equal to 0.5 and 0.8 by reference to the envelope of figure 8. In figure 9, the velocity U in the formula for the inertial impaction parameter K has been assigned values from 0.1 to 0.5 meters per second. In figure 10, the value assigned to U is the gravitational settling velocity of unit-density spheres with diameters shown on the ordinate scale. According to figures 9 and 10, in order to achieve inertial impaction efficiencies of 80 percent with aerial spray droplets, the droplet diameter must be of the order of 100 microns.

Turbulent deposition or impaction has been defined in two ways, both of which depend on the existence of large velocity fluctuations. Turbulent impaction is generally interpreted to mean that an aerosol particle or

droplet is physically transported to the surface of an object by a turbulent eddy and impacts on the surface. Turbulent deposition, on the other hand, refers to the fact that particles or droplets caught in vortex circulation or wakes in the lee of obstacles are brought to stagnation points or dead zones near the surface of foliage or other objects where the vortex circulation vanishes and the droplets or particles are thus deposited on the surface. This phenomenon has been offered as an explanation for the observed presence of small spray droplets on the undersides of leaves in canopies and other objects which cannot be explained as the result of either gravitational settling or inertial impaction.

Other processes such as electrostatic attraction, adhesion, and absorption are probably also effective under certain conditions. For example, there is evidence that some insects capture small droplets or particles by the action of cilia or by excreting a sticky substance.

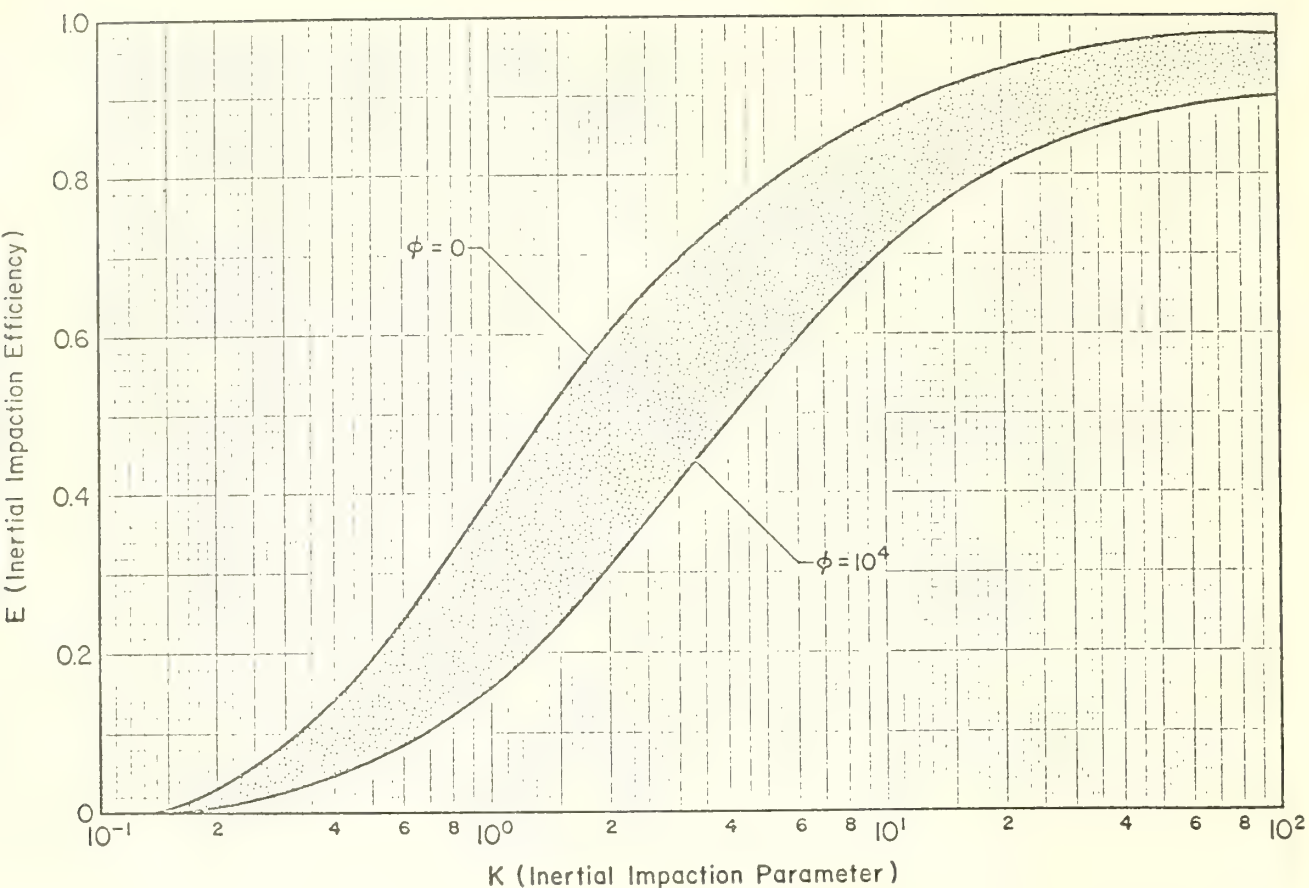


FIGURE 8. Inertial impaction efficiencies for circular cylinders;
 $\phi = \left(\text{Re}_p \right)^2 / K$. (From Golovin and Putnam 1962)

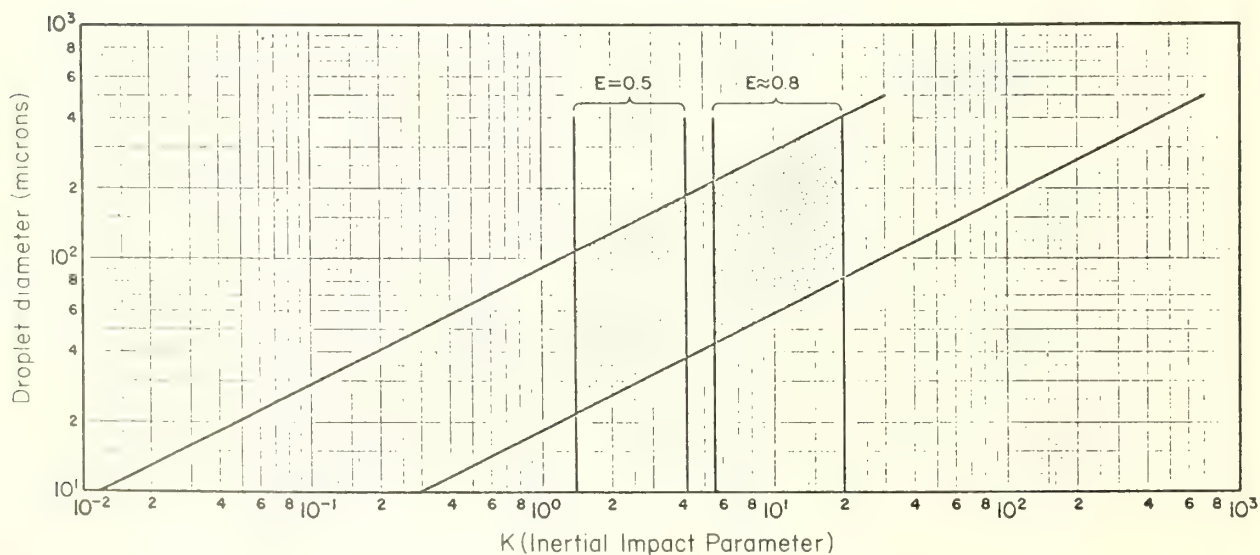


FIGURE 9. Minimum droplet diameters required for inertial
 impaction efficiencies of 0.5 and 0.8 when u varies
 from 10 to 50 cm sec^{-1} and D_t varies from 0.1 to 0.5 cm.

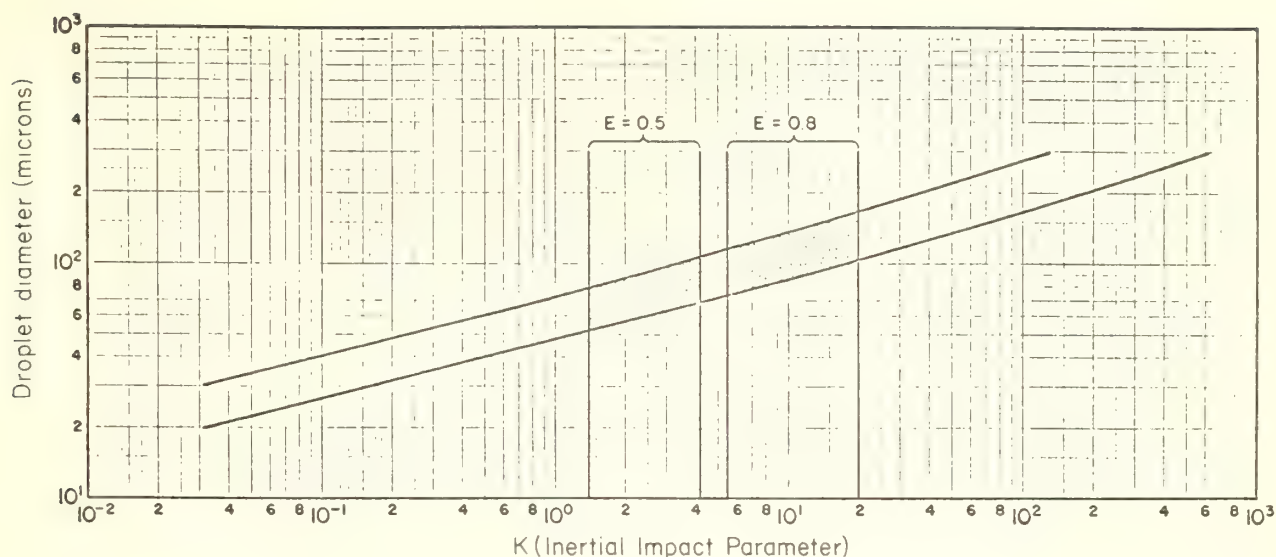


FIGURE 10. Minimum droplet diameters required for impaction efficiencies of 0.5 and 0.8 when $u = v_i$ and D_t varies from 0.1 to 0.5 cm.

A very simplistic view of the over-all problem of the optimum droplet size for aerial sprays intended for controlling insects in forest canopies--in the absence of such special phenomena as the capture of small droplets by cilia or adherence to sticky surfaces--is that the presence of small droplet sizes (drop diameters less than 20 microns) appears to be generally undesirable for the following reasons:

- Gravitational settling and inertial impaction are not very effective in depositing droplets of this size on the targets
- The efficiency of other processes is not sufficiently well established at present to justify dependence on these processes
- Retention of small spray droplets within the canopy is difficult and the problems associated with spray drift to nontargeted areas are maximized

COOPERATIVE PROGRAM REVIEW

To date, Deseret Test Center has provided limited meteorological support as well as droplet and aerosol sizing in support of four programs sponsored by Region One and the Missoula Equipment Development Center, U.S. Forest Service. On all four, Zectran was the insecticide used. Two of the programs involved a special dry formulation of Zectran. These tests have been reported by Barry and others (1972, 1973). In the other two programs, Zectran was diluted in fuel oil and released from both fixed wing and rotary wing aircraft as a coarse droplet spray. The first test involved the operational evaluation of a prototype military spray system. Testing was carried out both at Dugway, Utah, and the Lolo National Forest, Montana. Test results have been reported by Taylor and others (1972). Although the report cited is primarily an evaluation of military hardware, droplet spectra data derived from calibration runs conducted at Dugway are presented. The second operation, under the sponsorship of the U.S. Forest Service Pacific Southwest Forest and Range Experiment Station, was carried out near LaGrande, Oregon. The insecticide used was the Zectran-fuel oil mixture remaining after the Montana program.

Canopy penetration data obtained are shown in figures 11 and 12. The graphs generally follow the format developed by Hurtig and others (1953) to evaluate the screening effect of balsam fir foliage on coarse aerosols of DDT. In the figures, total mass beneath the canopy has been divided by the mass recovered in adjacent open areas. The mass ratio has then been plotted for each droplet size interval. Ordinate values can thus be read directly as percent penetration for a given droplet size interval (interval mid-points are plotted). Figure 11 shows both the first Oregon trial and the single Montana trial. Penetration factors are remarkably similar. The tree stand in Oregon was a dense clump of Douglas-fir surrounded by open meadow. Sampling (printflex) cards were placed 10 to 12 inches apart beneath the trees and in the open meadow. In Montana, fir was placed at 50 yard intervals over an area of several square miles. In Oregon, a helicopter was used, flying 75 to 100 feet above the canopy. In Montana, release heights of 200 feet were reached, with a fixed wing C-47 aircraft. Both operations, however, were daybreak operations

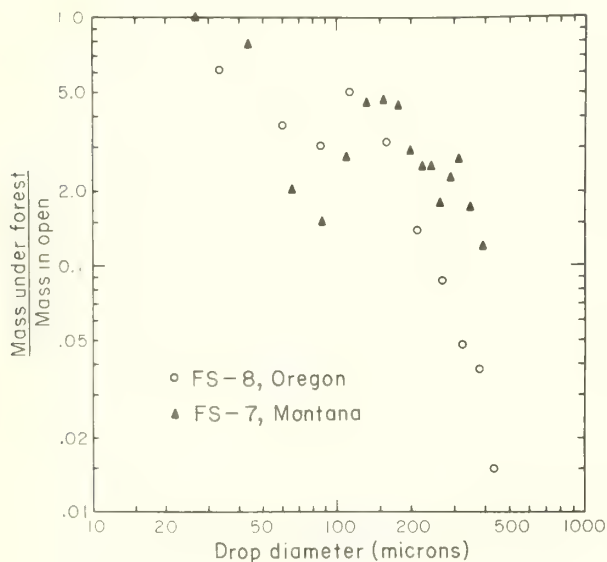


FIGURE 11. Percent penetration of a coniferous canopy for coarse Zectran fuel oil aerosols released under similar conditions of atmospheric stability.

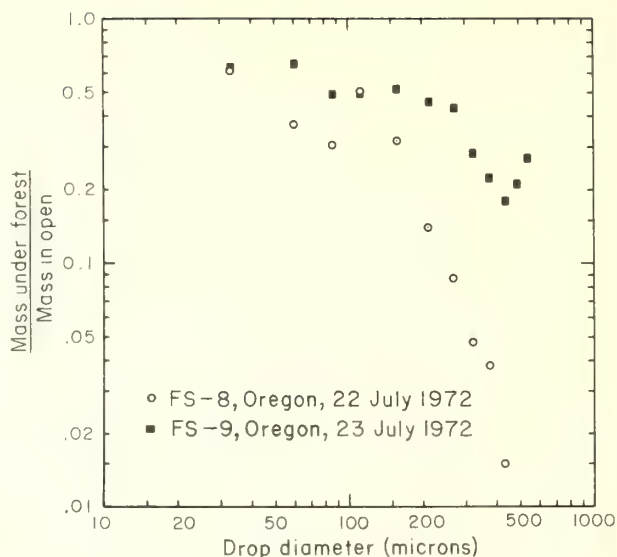


FIGURE 12. Percent penetration of a coniferous canopy for coarse Zectran fuel oil aerosols released under differing conditions of atmospheric stability.

(neutral atmospheric stability) and winds aloft were calm. That is to say, with similar stability regimes, there is a marked similarity of penetration ratios for quite different operating conditions. Figure 12 shows the two Oregon trials. On the second, fir trees more sparsely spaced dominated the sampled tree stand. Also, there was some understory broadleaf growth. No change was made in spray system parameters for the two Oregon trials; however on the second trial, the sample cards were arrayed on a steep slope and there was a light but detectable up-draft at the time of spraying. To the observer, the visible cloud had a slight but noticeable up-slope displacement. The 30-micron droplets coincide. With that exception noted, the slopes of the two lines are quite different. Such a small sample size cannot be conclusive. The data do stress, however, the importance of normalizing spray trial results in terms of the meteorological structure at the time of spray release as an essential prerequisite to any evaluation designed to compare biological effectiveness of pesticide application on coniferous forests.

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Impaction of Zectran Particles on Spruce Budworm Larvae

A Field Experiment

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Abstract--The U.S. Forest Service, supported by Deseret Test Center, conducted a field test during June 1972 in the Lolo National Forest, Montana. The objective was to investigate the impaction of dry-liquid Zectran particles on the western spruce budworm larvae as a function of particle size. A helicopter was used as the dissemination vehicle because of the downwash effect, which assists aerosol penetration of the forest canopy and enhances particle impaction. Rotorod samplers and glass impaction slides were used to obtain aerosol and particle-size data. Budworms and fir needles were examined, and impacting particles were counted and measured. Eighty-seven percent of the particles observed on the fir needles were 10 microns or less in diameter, and 87 percent of the particles observed on the budworms were 15 microns or less in diameter. The results and conclusions through based upon relatively limited data, provide baselines for planning future experiments.

Research work conducted by the U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station (Himel and others 1965, Himel and Moore 1967, Ekblad 1971), with the insecticide Zectran has disclosed that the highest rate of mortality of western spruce budworm (*Choristoneura occidentalis* Freeman) was achieved by contact with drops less than 50 microns in diameter. In an effort to produce small drops with standard dissemination equipment, a technique for developing a dry-liquid particle has been investigated. Dry-liquid insecticides are composed of a liquid formulation which is coated on a solid particle by a special blending process. The resultant

material may be up to 75 percent liquid by weight and still retain the free flowing properties of a granular solid.

Spandav (1944) reported that scientists in Germany were the first to use the dry-liquid concept (originally called carrier-dust) as a means for employing chemical agents which could not be dispensed by the usual methods. These scientists thoroughly investigated the use of alumina gel and fuller's earth as carrier-dusts. In general, they concluded that any substance could be dispensed on a carrier and that the use of carriers offered a new method for dispersal of viscous or gum-like materials and of those materials which could not be prepared in a finely divided form by grinding, such as naturally occurring poisons and bacterial toxins.

In 1948, the research begun in Germany was investigated by the U.S. Army Chemical Corps at Edgewood Arsenal, Maryland (Wilcox and Goldenson 1951, 1960). Physical characteristics of carriers were defined, and feasibility of the carrier-dust technique as a means for disseminating chemical agents was demonstrated.

In 1947, oil solutions of DDT were mixed with micronized dust (Brooks 1947) and dispersed from an aircraft by means of a dust-feed disseminator. This method was used to increase the particle size of the dusts.

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Insecticide dusts were commonly used during the 1940's and 1950's. However, the dust particles were generally less than 10 microns in diameter. Low impaction efficiencies, lack of retention on leaf surfaces, and drift problems associated with these small dust particles resulted in a shift of the use of liquid sprays consisting of larger droplets. The origin of the term, dry-liquid, is unknown although the term has been in use at the Edgewood Arsenal for some time.

The number of casualties from malaria and other insect borne diseases in the Pacific theater in World War II was equal to or greater than those from enemy action. This fact led the U.S. Government to sponsor extensive studies to understand the insecticide modes of action involved in reaching, impacting upon, and killing the target insects.

The timely availability of DDT and its apparent effectiveness in very low concentrations compared to other insecticides provided the military with a new chemical for possible control of disease vectors.

In order to design equipment for dispersing DDT efficiently, however, information was first needed on the optimum particle size. Without such information it would be impossible to take full advantage of the toxic properties of DDT, material would be wasted, and control would frequently be impractical. The particle size required to obtain the maximum effect would depend not only on factors peculiar to the insecticide, such as susceptibility of the insect to the insecticide, its mode of action, and its chemical and physical properties, but also on such external conditions as meteorological factors, terrain, and method of treatment.

The problem of optimum particle size of insecticides has been the subject of investigation by a number of workers for many years before the discovery of DDT. Smith and Goodhue of the U.S. Department of Agriculture (National Defense Research Committee 1946) summarized some of the earlier work on the relationship of particle size to insecticide efficiency, and concluded that the toxicity of solid-type insecticides increased with decrease in particle size.

Dry-liquid mixtures consisting of desired particle sizes offer several distinct advantages over liquid mixtures, such as: (1) ease of handling and storing, (2) ease of dissemination, (3) simplicity in laboratory assessment, and (4) minimum evaporation. Because of these advantages, the U.S. Forest Service investigated the dry-liquid concept and determined that the registered Zectran FS-14

formula⁷ could be coated onto a dry particle of selected size.

In 1971, a field experiment to investigate the feasibility of using dry liquid, was conducted in the Nezperce National Forest, Idaho (Barry and Blake 1972). The material disseminated was Zectran FS-15 coated on Micro-Cel E with a fluorescent tracer, Tinopal. The formulation of this mixture was a joint effort by the U.S. Forest Service's Pacific Southwest Forest and Range Experiment Station and the Missoula Equipment Development Center. The formulation consisted of 60 percent FS-15 and 40 percent Micro-Cel E. A single aerial line release was made using a Cessna Agwagon aircraft with a Swathmaster dispenser. Drainage winds were utilized to transport the dry-liquid aerosol throughout the designated test area. Surface samplers, placed throughout the test area, indicated that most of the area was covered by the aerosol. However, very little reduction in budworm population was noted and very little particle impaction was observed on the foliage. It was postulated that lack of impingement was the result of a very low impaction efficiency associated with the small particles which made up the aerosol. Over 80 percent of the particles, as measured in the laboratory, were 4 microns or less in diameter and further, approximately one-tenth of the recommended rate of Zectran was sprayed over the designated sampling area, i.e., 0.018 pounds of Zectran per acre instead of the required 0.15 pounds. The Tinopal tracer was unstable in light, which made microscopic assessment difficult. Also, Tinopal fluoresced blue, which complicated efforts to differentiate it from naturally occurring background material. This experiment, however, clearly demonstrated: (1) the feasibility of using dry-liquid as a means of employing insecticides; (2) that standard Swathmaster type dusters can be used to disseminate dry-liquid mixtures; and (3) that drainage winds in mountainous terrain can be employed to transport dry-liquid aerosols.

There is little information in the literature on the optimum particle size for impaction on spruce budworm larvae feeding on coniferous needles (except for the Himel and Moore study). There are, however, several studies which deal with impaction of particles on mosquitoes and with theoretical calculations of impaction of various size particles as a function of wind-speed, and of the size and shape of the impaction target.

⁷The Zectran FS-15 formula is made of 24 ounces of Zectran (4-dimethylanimo-3, 5-xylyl methyl carbanate) in solution with one gallon of tripropylene-monomethyl glycol ether (TPM).

Insecticide Mixture

The dry-liquid insecticide formulation consisted of a blend of the following, by weight:

Hi Sil 233	47.5 percent
Zectran FS-15	50.0 percent
Chartreuse Pigment 720	2.5 percent

Aircraft and Disseminator

A Bell G-3 helicopter equipped with a duster was used for spraying the dry-liquid mixture over the two test plots. The aircraft speed was 30 miles per hour, and the release height was approximately 50 feet above the canopy.

METHODS

The objective of this test was to investigate the impact of dry-liquid particles on the western spruce budworm larvae as a function of particle size.

The test was a cooperative effort between U.S. Forest Service and Deseret Test Center and was conducted in the Kennedy Creek area of the Ninemile Ranger District, Lolo National Forest, Montana, on June 28, 1972 (Barry and others 1973). A helicopter was employed to disseminate a dry-liquid formulation of the insecticide Zectran over two test plots in a Douglas-fir forest. The trees in the test plots were highly infested with western spruce budworm larvae.

The original scope of the test included several duplicate releases to compare liquid sprays to different formulations of dry-liquid sprays, in addition to comparing different types of disseminating aircraft. For economic reasons, however, the test scope was reduced.

Site and Test Plot

Plot 1 consisted of 217 stems per acre and Plot 2 consisted of 97 stems. Each test plot was approximately 200 feet wide and 300 feet long (fig. 1). The sampling array was identical on both plots consisting of 63 rotorod sampler stations. A glass impaction slide measuring 1 inch by 3 inches was positioned at each rotorod station.

⁸The mass median diameter is obtained by dividing the total volume of the spray into two equal parts; one half of the mass of the spray is contained in droplets of smaller diameter than the mass median diameter and the other half is contained in droplets of larger diameter.

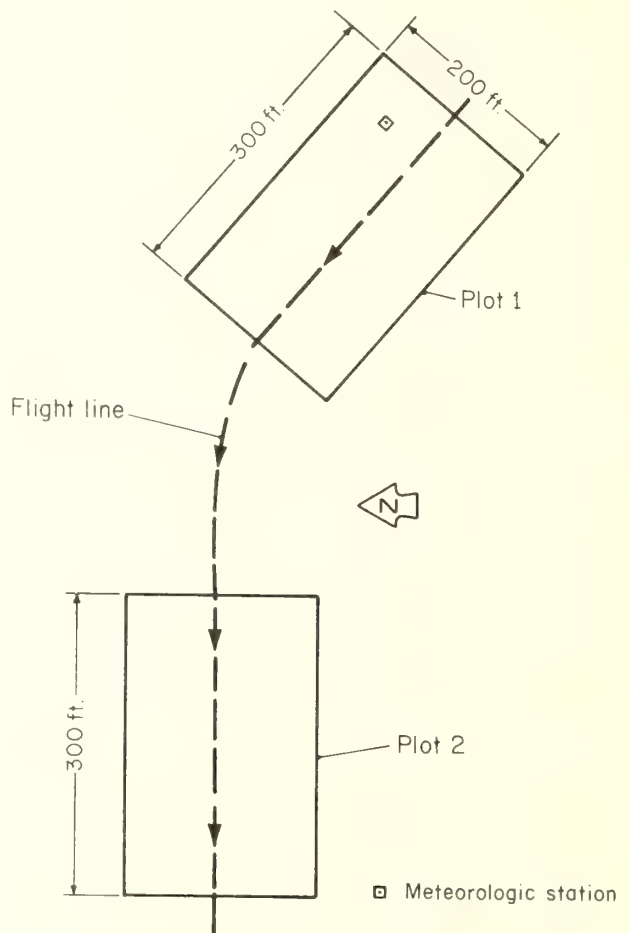


Figure 1. Orientation of Plot 1 to Plot 2 and Helicopter Dissemination Line.

Biological Sampling

A prespray insect survey was conducted in the test area approximately 24 hours before the spray release for the purpose of establishing prespray level of spruce budworm population. Branch samples were obtained to study particle impaction of foliage.

Four trees in each plot were selected as sample trees to investigate particle impaction on the budworm larvae. A plastic drop cloth was placed beneath each of the four trees to collect falling larvae. On the morning following the test, approximately 100 budworm larvae were collected at random from each drop cloth and placed in 35-mm film cans for transportation to the laboratory.

The fir needles and budworm larvae were examined under a dissecting microscope equipped with ultraviolet light for the presence of fluorescing dry-liquid particles. The particles were counted and measured.

Meteorological Instrumentation

Instruments to record windspeed and direction at the 2-meter level were positioned near the center of Test Plot 1. Wet and dry bulb temperature readings were taken at the same location during the test.

RESULTS

a. Eighty-seven (87) percent of the particles observed on the spruce budworm larvae were equal to or less than 15 microns in diameter; 87 percent of the particles on the fir needles were equal to or less than 10 microns in diameter; and, the majority of the particles on the fir needles were on the underside of the needle. Forty (40) percent of the particles on the glass plates were greater than 33 microns (table 1-5).

b. The number median diameter of the dry-liquid formulation was 1.3 microns and the mass median diameter was 37.0 microns.

c. Under the conditions of the test, the swath width exceeded 200 feet.

d. Budworm mortality was approximately 33 percent.

Table 1--Distribution, by size, of 150 fluorescent dry-liquid particles found on 108 spruce budworm larvae

Particle size (μ)	Number of particles	Percent	Cumulative percent by number
3-5	16	10.7	10.7
6-10	76	50.7	61.4
11-15	38	25.3	86.7
16-20	13	8.7	95.4
21-25	5	3.3	98.7
26-30	2	1.3	100.0

Table 2--Distribution, by size, of 191 fluorescent dry-liquid particles found on 4941 fir needles from Plots 1 and 2

Particle size (μ)	Number of particles	Percent	Cumulative percent by number
2-5	118	60.8	60.8
6-10	50	25.8	86.6
11-15	18	9.3	95.9
16-20	5	2.6	98.5
21-25	1	0.5	99.0
26-33	2	1.0	100.0

Table 3--Distribution, by size, of 355 fluorescent dry-liquid particles measured on impaction plates

Particle size (μ)	Number of particles	Percent	Cumulative percent by number
<2	28	7.9	7.9
2-5	26	7.3	15.2
6-10	23	6.5	21.7
11-15	34	9.6	31.3
16-20	48	13.5	44.8
21-25	24	6.8	51.6
26-33	31	8.7	60.3
>33	141	39.7	100.0

Table 4--Summary of percent of particle sizes observed on spruce budworm as a function of particle size distribution, by number, of particles disseminated

Particle size (μ)	Percent on budworm	Percent dissemination	Ratio:Percent disseminated/percent on needles
2-5	10.7	37.0	3.46
6-10	50.7	4.0	0.08
11-15	25.3	0.42	0.02
16-20	8.7	0.28	0.03
21-25	3.3	0.14	0.042
25-35	1.3	0.70	0.54

Table 5--Summary of percent of particle sizes observed on fir needles as a function of particle size distribution, by number, of particles disseminated

Particle size (μ)	Percent on budworm	Percent dissemination	Ratio:Percent disseminated/percent on needles
2-5	60.8	37.0	0.61
6-10	25.8	4.0	0.16
11-15	9.3	0.42	0.05
16-20	2.6	0.28	0.11
21-25	0.5	0.14	0.28
25-35	1.0	0.70	0.70

CONCLUSIONS

a. If the budworm is considered a cylinder 1/8-inch in diameter, the majority of the particles disseminated were too small for efficient impaction by inertial forces on the spruce budworm larvae, as illustrated by calculated impaction efficiencies in figures 2 and 3. The fact that small particles were observed on the larvae suggests that another mechanism or combination of mechanisms are causing impaction or deposition of particles on the budworms and fir needles.

b. Sell's theory (Sell 1931) can be used to estimate the particle/droplet size which has the greatest impaction efficiency for various objects, if the particle/droplet velocity and size of the impaction surface is known (table 6, fig. 4).

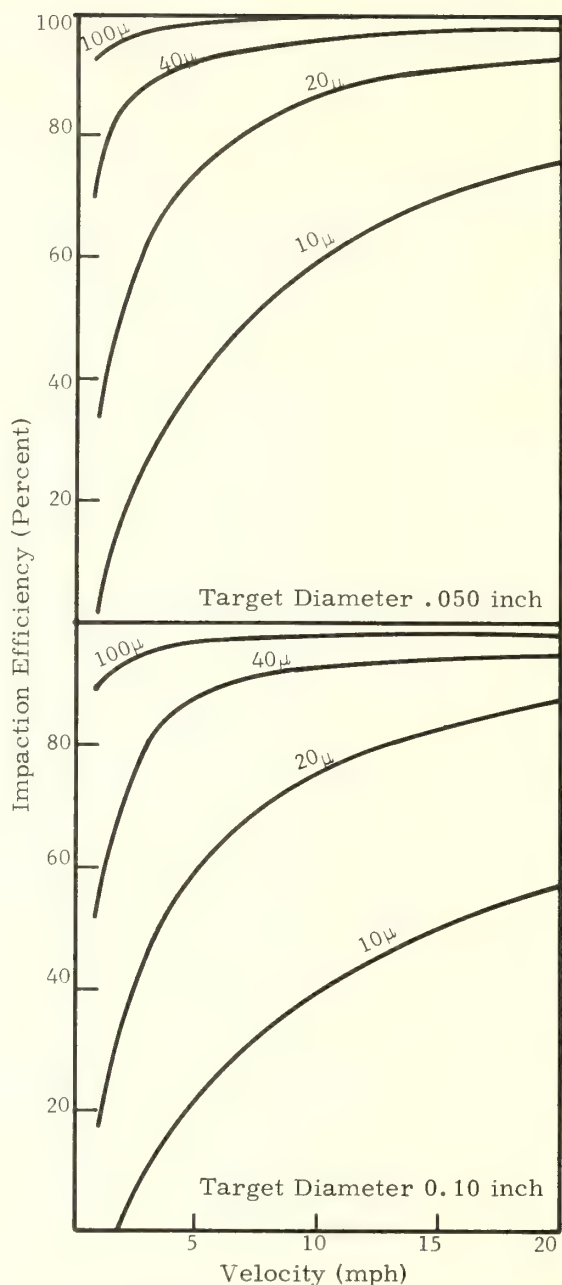


Figure 2. Inertial Impaction Efficiency of Various Size Particles on Cylinders of Various Sizes as a Function of Wind Speed Calculated from Golovin and Putnam (1962).

c. The particle size spectrum of the aerosol or particulate cloud and the horizontal and vertical wind velocity should be measured above and below the canopy in experiments designed to evaluate dissemination methods and the effects of various size particles.

d. The use of insect mortality data to judge the effectiveness of a new dissemination technique or system, without measuring the meteorological influences, should be avoided.

e. Helicopters provide a means of disseminating insecticides in complex mountain terrain with certain advantages over fixed-wing aircraft. Harnessing the downwash provides a means of overcoming or reducing unfavorable meteorological conditions. However, to be more effective than fixed-wing aircraft, the helicopter must be flown at speeds < 40 mph and close to the canopy (fig. 5). It is recognized that this may not be practical under many conditions.

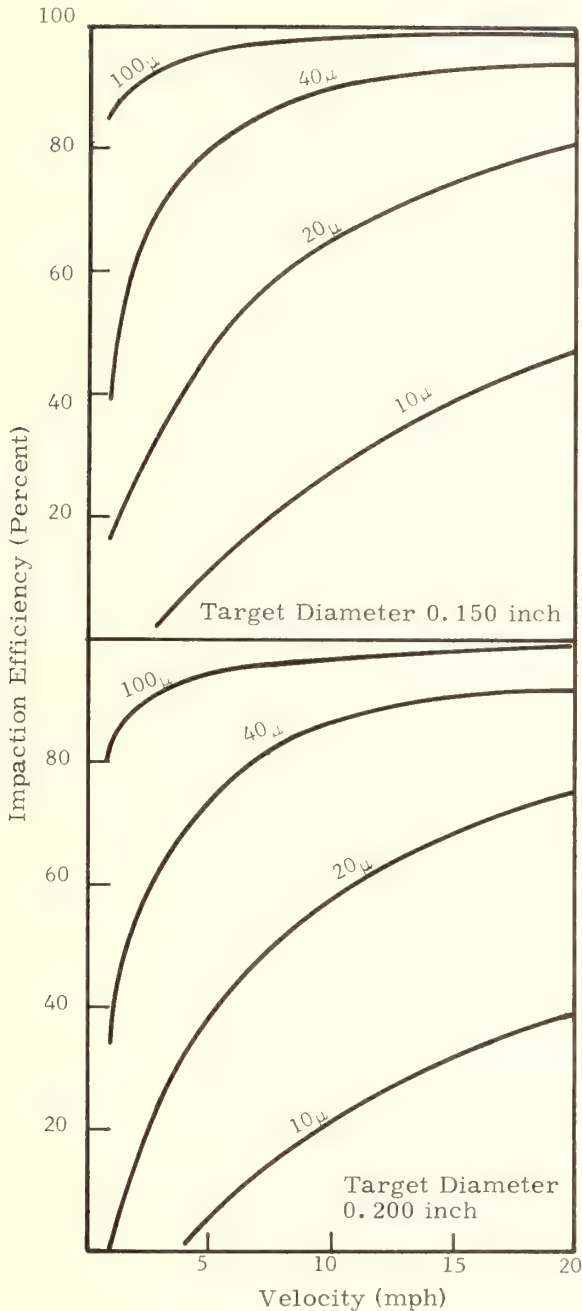


Figure 3. Inertial Impaction Efficiency of Various Size Particles on Cylinders of Various Sizes as a Function of Wind Speed Calculated from Golovin and Putnam (1962).

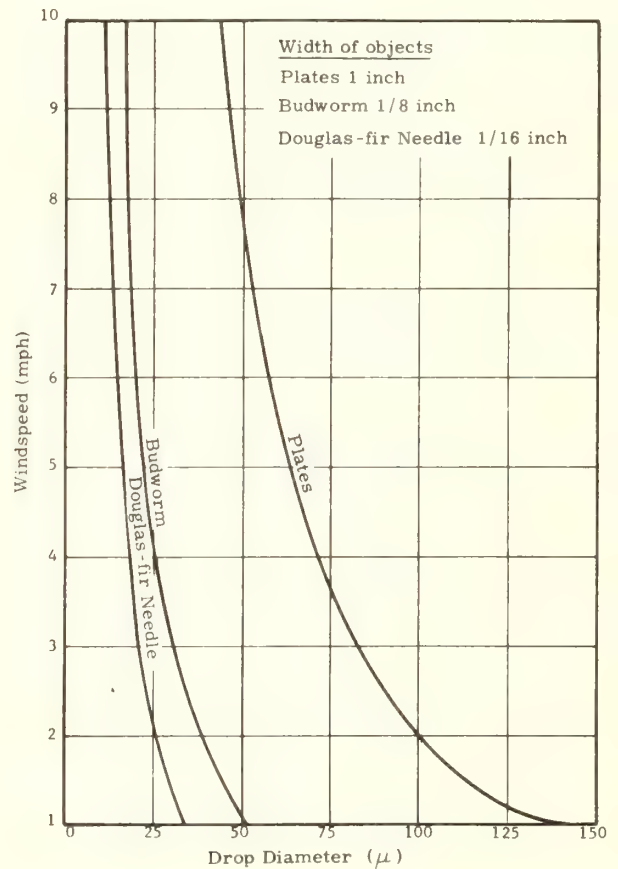


Figure 4. Relative Maximum Efficiency of Three Collectors as a Function of Wind Speed and Particle Size (According to Sell's Law).

Table 6--Particle size associated with maximum impactation efficiency (as a function of windspeed) on Douglas-fir, budworm, and glass plates, according to Sell's Law

Object (width)	Windspeed (mph)	Particle size (μ)
Douglas-fir Needle (1/16 in.)	1	35
	2	25
	3	20
	4	18
	6	14
	8	13
Budworm (1/8 in.)	10	11
	1	50
	2	35
	3	29
	4	25
	6	20
Plates (1 in.)	8	18
	10	16
	1	141
	2	100
	3	82
	4	71
	6	58
	8	50
	10	45

f. It was beyond the scope of this test to study the advantages and disadvantages of dry-liquids over those of liquid sprays. However, dry-liquids, aerosols or particulates, applied in the proper range of particle sizes may have certain advantages to control forest insects for specific applications, such as tree plantations, complex mountain terrain, seed trees, and specimen trees near recreation and summer home sites.

g. A simple and reliable method is needed for marking swath lines for aerial spray operations in forests.

h. The Hercules Chartreuse 720 fluorescent pigment is a satisfactory material for aiding in the microscopic examination of the dry-liquid particles.

i. Future research should be directed at answering such questions as how many droplets (of the size which has a relatively high impactation efficiency on the specific target) are necessary to give a high probability of contact with the target, and how many droplets of this size are necessary to produce a lethal dose of insect knockdown in the field.

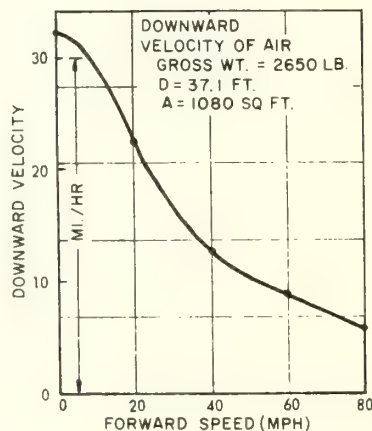
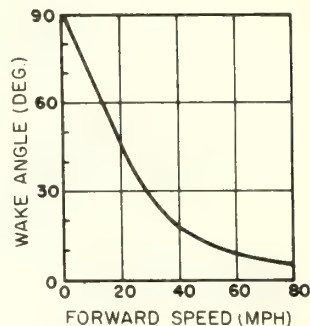
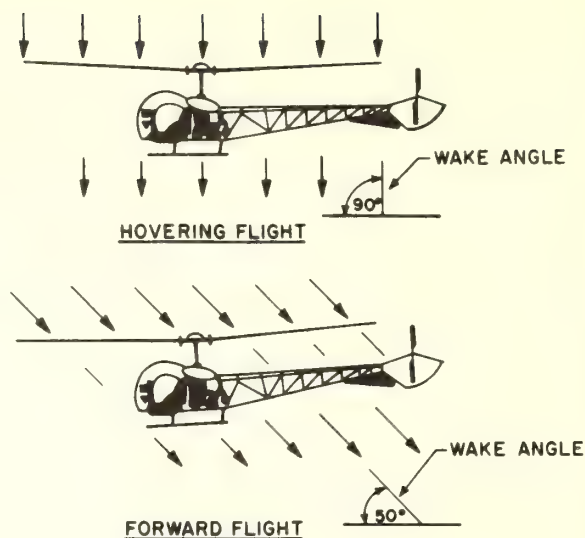


Figure 5. Helicopter Wake Angle as a Function of Forward Speed. (Source: Obtained from Bell Helicopter Publication "Helicopter Techniques for Aerial Application," Fort Worth, Texas, January 1966).

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Workshop Summary

Robert L. Dimmick¹

I shall present this as a chronology, because I think that a sequence of events can yield information not always visible in a categorized, historical recounting. Actually, our group just got started into the meat of the argument. We found (collectively) that we had a lot of knowledge, but it was difficult to combine and express it in a simple way because, surprisingly enough, semantics became a major problem.

We started by attempting to define behavior in its totality. We said, there is a source, there is the air, there is a target, there is the fate of a particle (it lands someplace), and there is the end result (it does something). Very quickly we decided this viewpoint was too large to consider, so we selected three parts. One part is the source, one is transport, and one is target.

Source must have several properties. We decided that devices used to produce aerosols were not part of our discussion and that the production of the aerosol was not part of the concept of behavior. We wanted to start with what we finally called a "stabilized aerosol." This immediately created semantic problems--an aerosol cannot be stabilized--what do you mean by that? When the argument was finally threshed out, we said a particle is emitted from a source, some evaporation (equilibration) occurs, and finally its initial production energy is dissipated and it "hangs" in the air--an aerosol particle. We even discovered that we were not sure what we meant by aerosols because people talked about aerosol "clouds." We decided that an aerosol is just a collection of airborne particles, and left it at that.

We then tried to define what we mean by "source." We started talking about the strength of a source. Then we said that "strength" is not exactly what we mean by "source strength" because that has connotations of how much active ingredient is in a particle. So we decided to call it emission rate: A source is defined by the emission rate of particles (material) going into the air times the time of spray.

Now we had the collection of particles hanging in the air. The first parameter we thought of was size, then size distribution. We agreed that size distribution is approximately log normal; the smaller the particle becomes the greater the number you expect to find. And the apparent size depends on the technique used to measure the particles. If you look into literature on measurements of size distribution, you get the idea that the absolute laboratory standard is to count and size them under the microscope; but even that has problems.

I was involved, for example, with some work with a pharmaceutical company that was making an aerosol product. They were having particle analysis (microscopy) done by an institute in the East. The company was not happy, since they were trying to use the data for quality control, and it varied unaccountably. So they sent the institute identical samples, but did not let them know that the samples were identical. The samples were returned with several different size estimates. So I finally convinced the company that what they were really interested in was the aerodynamic diameters; i.e., they should consider their product in terms of its behavior and not worry about the actual diameter of their odd-shaped particles. It was how well the particles penetrated into the lung that was the important parameter.

The panel kicked that idea around for a while and found we were again talking about a "stabilized aerosol"; you have material and you produce it as an aerosol and then it reacts with the air and comes to some sort of initial equilibrium. We said, what else besides size affects the aerosol? Well, the concentration does--and immediately the question arose, what do you mean by concentration? Someone said, "The number of particles per unit volume of air, that is the concentration." Someone else said, "No, that is not what we mean, we mean, how much active material is within the droplet."

How should we express concentration? Probably, one has to express it in some way that involves both of these properties: We decided to refer to the formulation as "composition" and the amount dispersed (the source strength) as concentration. We can all go home with dictionaries and look up some of these. What has all this to do with behavior? Certainly the chemical and physical properties, and the composition of the particle, affect the eventual behavior.

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We then turned our minds to the subject of transport of aerosols. We decided not to refer to air as a vector but rather as a process of transportation. There are a number of factors involved in transportation, but it was evident that a most profound factor with respect to transport of aerosols, as you might guess, was meteorological effects. As several speakers discussed meteorological properties, it became evident that some were talking about micrometeorological events, whereas others were talking about macrometeorological events, and the two were interlinked. For example, terrain is a factor that certainly affects the transport of aerosols (as it affects air) and is considered to be, I take it, a part of the meteorological picture--that is the macrometeorological part of it. On the other hand, some meteorological events include impaction of particles on the bottoms of twigs. We spent a considerable amount of time arguing about turbulent impaction, and I think if I may make a pun, we left that question up in the air. Perhaps we really did not understand how the particles got there and perhaps this is an area where somebody should do some work.

Under "transport" is included the idea of trajectory. Now, what do you mean by trajectory? We finally said as I recall it, "Well, depending upon the terrain and a lot of luck and everything else, the aerosol either goes in a straight line or it diffuses, or maybe it makes a bend; this phenomenon is extremely difficult to predict."

That statement is typical of committees, encompasses all knowledge and cannot be refuted; it is a reflection of the state of the art. However, there are a number of factors involved in the final trajectory, and in attempts to predict meteorological events, one thing that evolved from the discussion was that every parameter we talked about seemed to be interconnected with every other parameter. We tried but were unable to make a rational list of headings, subheadings, subsubheadings and so forth--something here belonged over there. Regardless, I will list some of the factors we thought might influence "transport": the effect of light on the particle, temperature, humidity, washout (washout, I believe, refers to fog in the atmosphere or rain or any action that reduces effectiveness), coagulation, photolysis, hydrolysis, evaporation, turbulence, diffusion, and time. Finally someone pointed out that, in the long run, the real problem involved accounting for 100 percent of the mass in making these measurements. If one can conduct experiments in such a way that he can account for 100 percent of the mass, then he is in a position to make meaningful statements.

During the course of the conversation we moved from trajectory and transport into "target." For a while we were not sure whether we were talking about transport itself or only about target. So we defined target as a two-valued word, target and nontarget. Here again semantics came up. What do you mean by the target? Take mosquitos. Is surface water (that you put insecticide on) the target, or is the mosquito larvae the target? One person talked about the target and I was confused until I realized that his idea of nontarget was something (e.g. cover) that kept the aerosol from getting to the target. There were at least two people talking about the same word and coming up with a different meaning. We wondered whether it is impingement or impaction when the insecticide gets on the target? Well, in my vocabulary impingement implies "going into" and impaction implies "going onto." That was not really brought out in the discussion, but it is again expressive of an attitude; we felt we had to begin defining our terms and explaining ourselves in simple language. Because we are in different fields, it is almost like speaking different languages.

We then moved to a discussion of the question what are the important factors making up a target. Well, the size of the target, the shape of the target, the location, the orientation of the target, and certainly the problems of the canopy effect (which was defined as shadow effects or as shelter effects) and the idea of "bounce-off," which implies that liquid particles larger than 50 microns might behave as elastic material and, as balls in a game of pool, rebound to a new trajectory. Mechanisms of gravity impaction and turbulent impaction and of ventilation within a canopy all have to do with the "target."

In summary, I feel that the group in general agreed that we need more research into micrometeorology. One of the earlier papers in this symposium referred to how the standard deviation of small vectors in a given body of air will give one a pretty good idea of what the whole cloud is doing. This certainly involved micrometeorological measurements. Some laboratory studies on turbulent impaction should be conducted under controlled conditions. I think it does not make too much difference what type of material you use to study turbulent impaction as a phenomenon. Using whatever type of material is easiest to look at and easiest to measure could be a starting point.

We need more effective measurements of size distribution. In our laboratory we do routine size analysis and we use whatever

technique seems to be most effective. But it depends upon the size you are talking about. If you are going to look at big particles and you are not concerned with how many of the little ones there are, then maybe the card method is fine. But if you want to know what is there, total and complete, you may have to apply more than one particle-sizing method--a card method for the large ones, and perhaps an optical-electronic counting method for middle size range. For the very tiny ones you will probably have to go to electrostatic precipitators or centrifuges.

Discussion

DR. DRUMMOND: My question probably should be directed to Mr. Boyle. I was wondering if his turbulent diffusion models have been proven experimentally or are they just a set of equations we saw on the board yesterday.

DR. CRAMER: Doug Boyle is not here, so I will field this question. Model evaluation is a terribly difficult area and has been part of my interests for the past 15 years or so. The problem is that we hardly ever get our hands on enough data of the right kind to do model validation. The number of degrees of freedom required for statistical significance is probably around one per field trial. So because of the pressing problems that were discussed here, where we need answers we are proceeding in an evolutionary way. We are developing the best concepts that we have. We check them as we can and the model itself is really very simple. It is a mass continuity model to try and keep track of everything. To date, the experience is that where we are able to obtain good measurements, there are very few surprises in comparing the measurements and the predictions. Actually the model predictions give us a reasonably high quality of input information and are much better than the measurements by and large. So I think the answer is that we are now proceeding on the assumption that we have provided in the model for the processes that do occur. There is a judgment to be made as to how well the model will actually fit any data. When we get a chance to do that we might have considerable confidence in the modeling techniques that Mr. Boyle was describing. But it is going to be a very long time before we are sure that they are absolutely correct.

DR. DRUMMOND: If I may make a second comment about macrometeorology and micrometeorology. It seems to me that they are characterized by

Finally, we said that it would be nice if we had some concept of how to make aerosols go where we wanted them to go. If you could just define the target and define the nontarget, and then if you could come up with some kind of a magic box which would cause particles of just the right size to go exactly where the target is and nowhere else, then we would be doing the job. I know that sounds rather dreamlike, but the idea probably ought to be kicked around before we claim to be experts on behavior.

just two parameters, the scale and the intensity of the turbulence. If the model works, why not use the same model under the canopy, because the same physics are applying, only the size of the parameters are different.

DR. CRAMER: Not quite right, I would say, but there is great merit in what you are saying. There is a limit, below the canopy problem, if the canopy is presumed to be a formidable barrier. There is a different kind of meteorology involved in some of the important details--very low wind speeds, for example, or transport speeds and some of the bulk concepts that work terribly well, in the open, we will say, have to be modified. It was our hope, in terms of this over-all problem of release into the tree air and going into the canopy, that there has got to be an amalgamation here, but we are not quite sure yet what you have to do under some conditions--under some canopies--to tie these two types of processes together. But in the end, I am sure we will work it out.

DR. MOORE: I would like to direct this question to Dr. Roberts. A few years ago you were doing some work with ruby laser holography, which if I can recall your work, will define the size distribution, and the behavior of the particle. Is this process impractical for any of these research purposes?

DR. ROBERTS: At this time the laser holographic process is still a lab tool. We had hopes of taking it into the field, but you have to set up fairly artificial conditions to obtain results. It is true that you can get drop spectra, however, 1 micron is the lower limit of the instrumentation. You can estimate drop size down to about 0.5 microns. You have to keep in mind also that the depth of field for focus on a hologram is the square of the diameter of the particle. So, if you have a

1-micron particle, you have one micron for the depth of field of focus, or with a 5-micron particle you have a 25-micron depth of field of focus. The other point to remember is that the field of view is limited to the diameter of the laser light, which is 1 cm. So that anything that passes through that field is going to be photographed. With the ruby laser, which has stop-action capabilities of up to 10,000 ft/sec, none of your spray particles are traveling at those speeds, so any particle that is passing through this 1-cm light path will be photographed and/or recorded on a hologram.

DR. HIMEL: In Doug Boyle's absence I want to reiterate some things that we discussed this morning and that he mentioned in passing yesterday and that I think are extremely important. I refer to his statement that "on a mass delivery basis you deliver the same mass with 100-micron droplets as you do with 20-micron droplets downwind of the spray area." Now to me this is extremely important, because in this process of looking at spray delivery, you have two major philosophies. One is gravity fall and that is an oversimplification, and the other is atmospheric transport and diffusion and that is an oversimplification. Now I do not want to take liberties with what Doug has said, and I am not quite sure I understand all he said anyway, but these two processes are in fact interrelated. But gravity fall has been the great philosophy and 100-micron droplets are at least reasonably large, and 20-micron droplets are reasonably small. To have this information--that on a mass basis you are delivering, by these transport processes, the same mass of insecticide downwind at any sampling station with either size droplets--is very important. The corollary then is that if you are in this aerosol range you are going to deliver downwind the same mass independent of drop size below 100 microns.

MR. PILLMORE: I was in the behavior workshop yesterday and in addition to the problem we were having in semantics we also had some other problems; different objectives, which I thought accounted for quite a bit of variation when we were trying to define target and nontarget. There were many different viewpoints. With respect to wildlife as nontarget organisms, I would like to give one illustration, and that involves droplet size as an exposure mechanism which can help to explain a lot of differences we may see in the field appraisal of insecticide effects. One of the most illuminating experiences that I have had was (in association with Dr. Himel) examining various insects for fluorescent particles following the 1965 Zectran applica-

tion in Montana. Earlier he said that the droplet sizes of over 100 microns were not important on the spruce budworm. Certainly they were not the ones killing most of the spruce budworm, but from the standpoint of avian exposure, droplets over 100 microns did occur and could be very important because these were the very first insects affected immediately following the application. Contamination levels of those first affected are the type of sample that is important in explaining exposure. At the other end of the droplet spectrum the aerosols probably reduce the contamination of the food substrate, but at the same time raise the question of whether or not there might be increased respiratory exposure, particularly of birds in flight.

DR. ROBERTS: With respect to the problem of respiratory inhalation, Dr. Dimmick, can you give us information on the inhalation studies you have conducted?

DR. DIMMICK: I am not sure that this is important in respect to behavior, simply because in our workshop we were not able to adequately define the target. However, I will briefly relate some of our findings. For example, if we exposed mice continuously to an aerosol of Dibrom of around 2 micron mass-median-diameter, it took 45 minutes before we could detect something wrong with the mice. We found their cholinesterase level was depressed to the point where these mice were not feeling very well. Under these same conditions we exposed Japanese quail for 2½ minutes and we observed 100 percent mortality. The respiratory toxicity of Dibrom in birds was increased about 100-fold by inhalation compared to that of ingestion. I think the point that Mr. Pillmore wanted to make was that of effective ingestion. Now, the effect of respiratory exposure to birds, especially in flight, which has never been looked at as yet, is so much greater than the ingestion problem that it probably needs to be studied much more than ingestion.

DR. CRAMER: At the risk of perhaps not adding anything to the discussion, I will say that it seems to me that diverse interests are represented here. From the point of view of the systems engineering, what we have to do is something like this. Describe a dispensing system if you will, a product, an aerosol cloud, and take it until we have accounted for all the mass for as long a time and distance as required, and this will vary with the written objectives. But after we have described the system and what happens in a very

general sense, then there is another loop that you have to go through, and then you can define what your requirements are, and what you must know about this. You can define the target at that point in a very particular way; then you go back through again and determine and perhaps eliminate some of the features of the operation which are of no interest to you. But I think it is that second loop that you have to go through in the requirements phase of it that is important, and if our approach is generalized enough, we will be able to meet all these requirements. But they do make a difference in the set of parameters that you have to consider.

DR. MAKSYMIIUK: Dr. Dimmick, did you have the opportunity to observe coalescence of droplets in your aerosol sprays?

DR. DIMMICK: I have, in a way, to disqualify myself because it became evident yesterday in our workshop that when I referred to an aerosol I was talking about particles less than 10 microns whereas others were considering particles larger than that. What little work we have done simply corroborates that reported in many publications on the theory of small-particle coagulation. In general, if there

are less than 10^6 particles per cm^3 , then coagulation is negligible; if the number is greater than that, coalescence occurs as a second-order phenomenon. I have little knowledge of what happens with larger particles.

DR. MAKSYMIIUK: It might interest you that in the Beltsville lab it was found that we could not demonstrate any coalescence of spray drops in the air in the range of a medium spray atomization. We used two spray booms systems on the aircraft. One system contained a blue dye and the other one contained a yellow dye, and we never found green drops on our deposit sample surfaces. But this does not apply to you, since your drop size was probably beyond the range that we investigated.

DR. HIMEL: On this question of multiple-converging impingements, we do not have really quantitative data on it, but I think that our data from the large spray room that I referred to yesterday indicated that this is a very real factor, but obviously a function of concentration. I cannot quantify the concentration, but under the conditions used in pest control, the coalescence and converging impingement of droplets I think is a very real problem.

ASSESSMENT

Assessment of Insecticide Spray Processes

Chester M. Himel^{1, 2}

Abstract--A critical need exists for field methods by which actual delivery efficiency of insecticide spray methods can be assessed. When that is accomplished, we will be able to determine the relationship between efficiency of sprays and their droplet deposition on cards, slides and other impingement devices. We will have a new basis for monitoring field spray applications.

New analytical instruments and new tracer molecules offer a reasonable potential for new assessment methods. Quantitative study of the interrelationship of meteorological effects, mass transport, and spray droplet size can be the basis for great improvement in our methods for spray delivery. Such an increase in efficiency is a logical approach to the solution of the insecticide problem.

In the application of insecticides to target insects we are in the spray delivery business, yet, tragically, we have had no means of measuring our delivery efficiency. Our delivery systems have all the subtlety of a dump truck. We worry greatly about small amounts of pesticides that are air-borne and may drift downwind. At the same time, we virtually ignore the massive ecosystem contamination that results from an unmeasured dump of pesticides into the target area. After decades of use of insecticides, there are still no unequivocal data on area-related mass transport. That ecological, scientific, and economic tragedy stems directly from the virtual absence of fundamental assessment methods and research.

Insecticides are delivered to target insects and enter the environment by complicated processes whose mechanisms are poorly

understood. In spite of the economic and ecological significance of insecticides, and their widespread use, all application methods are empirical. They are empirical because adequate, quantitative, analytical assessment methods have not been available. Application methodology was developed at a time when efficiency in the use of insecticides, and insecticide residue problems, were not recognized as important. Now, we face the absolute necessity of making the use of insecticides compatible with the protection of the environment.

The entire insecticide controversy is based on the empirical nature of spray delivery processes. In the absence of quantitative data, controversy started and continues unabated. Today, all agricultural, legal, economic, and ecological decisions are based on the results of processes whose mechanisms are poorly understood.

The transport of insecticides to target insects involves a complex mixture of meteorological and physical parameters. We need a basis for measurement of those parameters. They include, in part, the physics of atmospheric transport, diffusion, and impingement, plus meteorological and micrometeorological effects. In this complex world, we have been in a scientifically untenable position. We have had no quantitative facts on which to base a rational analysis of our problems.

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²Acknowledgment: I am indebted to my colleagues at the Pacific Southwest Station and at the University of Georgia for their many contributions to the research discussed here. At the University of Georgia, I have had the able assistance of Dr. Richard Mayer, Dr. Solang Uk, and Dr. J. Philip Keathley.

It was a scientific, economic, and ecological tragedy that quantitative assessment methods were not available in the 1950's and 1960's when the present ecological problems started. Millions of man-hours of research, government, industrial, and legal time have been and are being expended on the postapplication problems of insecticides and their ecosystem effects. The delivery system which causes these problems, and hence is responsible for all the time and cost, is largely ignored. Its efficiency may be less than 1 percent, yet it has not been measured! A substantial increase in efficiency to even 50 percent would virtually solve the "insecticide problem." To do that, we need new, highly sensitive quantitative assessment to measure target-area mass transport. It is true that a few years ago, such research was virtually impossible. Today, however, the requisite analytical instrumentation exists or can be developed, and today the many complex meteorological problems can be successful. These new instruments and methods can give us new facts to replace empiricism. We can attack our problems from an accumulation of new knowledge. The seeds of the present management crisis were sown when this was not impossible.

It is my purpose to review briefly just where new assessment methods will allow us to go in the future. It is also my purpose to show that the basis for effective solution of the "insecticide problem" is within our reach. We will be able to do all of those things which will ultimately be known as the concept of ultra-low dosage (ULD)—the concept of maximum efficiency in the use of insecticides. It is insect control with minimum use of insecticides. When we are able to put efficient control systems together, our results will be orders of magnitude better than those we have today.

OLDER METHODS

In the less complex and more relaxed era of the 1950's, assessment of insect control methods were limited to (1) analysis of target insect mortality and (2) spray droplet impingement devices, such as silicone slides and impingement cards. These are crude, imperfect, and nonquantitative assessment methods. For example, the simple physics of impingement of spray droplets on silicone slides has never been studied seriously, yet they are important field assessment tools. Dr. Keathley has shown that the forces of attraction of a liquid droplet-to-silicone surface are greater than

the surface tension forces of the impacted liquid.³ Thus, apparent droplet size on a silicone slide is a function not only of the droplet's actual size but also its velocity of impact. Finally, critical impingement velocity considerations prevent measurement of spray spectra of airborne sprays with silicone slides or impingement cards. The correlation with insecticide delivery to target insects is unknown. In the meantime, spray cards continue to be our most popular field assessment method.

One of the major problems inherent in the use of impingement slides and cards is their bias against impingement of droplets smaller than the range of 40 microns. In addition, spray droplets coalesce or evaporate in the air prior to impaction, or two or more may impinge on identical areas. The problem of multiple converging impingement (droplet-droplet coalescence and multiple droplet impingement) is important. It can make impingement data equivocal and artifactual. The biological evaluation of mortality and impaction measurement of spray spectra are inadequate as assessment methods. One of the critical deficiencies of the past was the absence of any method by which spray droplets could be traced by size to target insects in their natural environment.

The first breakthrough came in 1965 when Himel and coworkers at the Pacific Southwest Forest and Range Experiment Station and the University of Georgia developed the fluorescent particle spray droplet trace method (FP method) (Himel and others 1965; Himel and Moore 1967, 1969; Himel 1969a, 1969b, 1969c, 1969d). That method was the first assessment method for evaluating spray droplets by size and number on target insects in the field and showed the critical importance of airborne-size spray droplets in the delivery of insecticides to insects. It did not give data on how they were delivered, only the fact that they were delivered. The effect of the number of fluorescent particles, and their relation to droplet size, is shown in table 1.

The FP method makes possible experimental detection of the size of the droplets transported to target insects in their natural environments. If the droplets found on target insects are 200 microns and larger, then gravitational delivery systems are operational. If, however, only airborne-size droplets are found, atmospheric transport systems are the

³Keathley, J. Phillip. 1972. Unpublished data.

Table 1--Number of fluorescent particles (FP) in droplets of various sizes at three particle concentration levels

Concentration of FP in spray (particles per milliliter)	Droplet size at ...				
	1FP	5FP	10FP	100FP	800FP
	<i>Microns</i>				
1 X 10 ⁸	27	46	60	130	260
2 X 10 ⁸	21	36	46	100	200
2 X 9 ⁸	10	17	21	46	92

critical factors in delivery. If the delivery of insecticide to target insects is based on atmospheric transport, then the efficiency of our delivery systems can be improved by orders of magnitude. That improvement can eliminate the "ecological problem of insecticides."

The FP method allows absolute differentiation between 20- and 200-micron droplets. Therefore it allows absolute differentiation between the two possible transport mechanisms. Because of its probability basis, differentiation between narrow ranges of droplet sizes is virtually impossible with the FP method. Suspension of FP in spray liquids is difficult; therefore the lower limit of detectability of droplet sizes by the FP method is in the range of 10 to 15 microns.

In spite of FP method data (and the widespread use of particulate meteorological tracers in meteorological research), the great entomological cliché that "small droplets never get down" is still with us. It is scientific and experimental nonsense, yet it persists and continues to cloud experimental facts. Airborne spray droplets are the predominant sizes delivered to target insects. They are affected by meteorological factors and by physical delivery systems. When all systems operate effectively, target insect control is good, and when they operate ineffectively, target insect control is low, yet we know very little about *how* those physical and meteorological processes operate. That is the challenge of today: to develop quantitative methods by which we can assess insecticide delivery systems and mass transport. Data on delivery of insecticide spray droplets to target insects are given in table 2.

The data in table 2 were determined by identification and counting of over 100,000 spray droplets on the target insects. There

is no evidence that large droplets (greater than 200 microns diameter) have any significant contribution to target insect control under these conditions. Because of their disproportionate mass they are the major factor in the environmental contamination problem. In the above experiments, spray droplets smaller than 20 microns contained zero FP and were invisible.

The next major breakthrough came 5 years later when Roberts and others (1971) showed that laser holography could be used to determine the mechanism of impaction of 1 to 5-micron-diameter spray droplets on insect setae. The data are extremely important and represent an elegant contribution to insecticide assessment research. They show experimentally that 1-micron-diameter droplets can deliver insecticide to target insects, and they place the optimum size for spray droplets in the range of 5 microns.

As indicated previously, there are two major theories as to the mechanism of delivery of insecticides to target insects. The first and most widely accepted is that spray droplets fall by gravity and impinge on the target insect, or on foliage which the insect traverses or eats. In spite of decades of research, no unequivocal experimental data support this theory. The reason is very simple--all sprays from commercial spray devices contain significant numbers and volumes of the airborne spray droplets. They are ubiquitous, usually measured, and often assumed to be absent. In their presence, no unequivocal data on the mechanism of insect control by gravitational fall is possible. A typical spray spectrum is shown in figure 1.

Table 2--Size of droplets found on insects

Target insect	Proportion of droplets in diameter class (microns)			
	20-50	50-100	100	200
	<i>Percent</i>			
Spruce budworm	97	3	0	0
Boll weevil (adult)	99	1	0	0
Bollworm (larvae)	99	1	0	0
Cabbage looper (larvae)	99	1	0	0

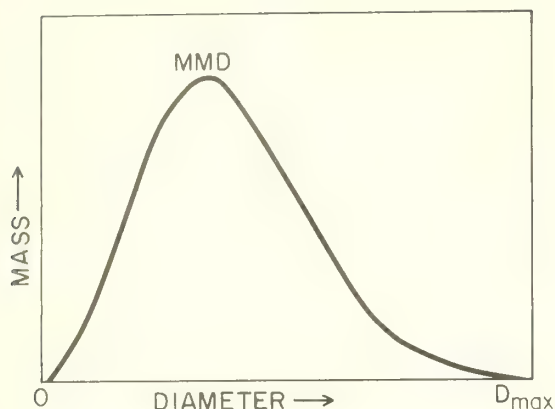


Figure 1. Typical spray spectrum;
mmd = mass median diameter.

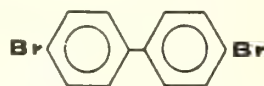
The second and most controversial theory of spray delivery involves the physical concepts of atmospheric transport and the impingement of airborne-size droplets. Such droplets are limited to less than 100 microns and are generally less than 50 microns. Their delivery to target insects in a foliage environment depends on physical and meteorological parameters that are complex and difficult to measure. Finally, the efficiency of airborne spray droplets in very small sizes is limited by critical impingement velocity considerations and by volatility. In our laboratory we have shown the existence of a foliage-air interfacial barrier which is an important factor in the delivery of airborne spray droplets to insects within a foliage environment. It means that droplets of this size must be driven into a foliage environment. In the field, this is accomplished by the meteorological effects of a flying airplane, or by the hydraulic-pneumatic spray from ground equipment. If we are to understand spray processes, we must be able to study the processes by which they breach the foliage-air interfacial barrier. Some new concepts in analytical methodology are available for this purpose and will be outlined below.

NEW METHODS

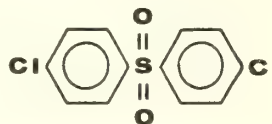
In the past, spray assessment methods have been largely concerned with measurement of spray droplet size. A weight or mass balance in the target area has been beyond the sampling techniques and analytical methods available. Most attempts at mass analysis have required incorporation of dyes into sprays. Most dye molecules are not

designed for purposes of pesticide analysis. For this reason we have studied the design of special tracer molecules. They must have known stability, known metabolism rate (in the biosystem), and known spectroscopic responses. Our greatest experimental success, however, has been with designed molecules that can be used with gas-liquid chromatography (GLC). The requirements for such molecules are that they be (1) nontoxic, (2) unique to the environment, and (3) adapted to GLC or mass spectrometric analysis at very high (nanogram) or picogram) sensitivity. Two typical examples of new insecticide tracer molecules are given in figure 2. In our laboratory, we have studied a whole range of analogs and homologs of such tracer molecules as new tools for the study of mass transport of sprays and insecticide movement in the ecosystem.

New methods for mass analysis of spray distribution are of little value unless clean, readily available, impingement devices of known characteristics are available. We have, therefore, designed a series of quite small glass devices which we are testing for impingement efficiency. Glass devices are of particular significance because they are clean and contribute no biological contaminants to mitigate GLC or mass spectrometric analysis. The physics and meteorology of spray impingement are well known and efficient mass sampling devices for research are well within the current state of the art. A simple and efficient capillary impingement device (CID) is illustrated in figure 3.



P, P'-DIBROMODIPHENYL
(DBD)



P, P'-DICHLORODIPHENYL SULFONE
(DCDS)

Figure 2. Insecticide tracer molecules.

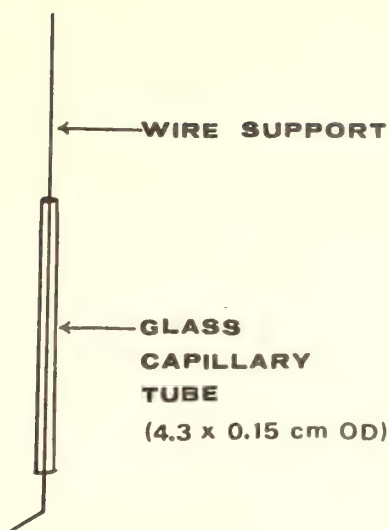


Figure 3. Capillary impingement device (CID) used in assessing airborne concentration of spray toxicant.

For several years, we have investigated the feasibility of actual analysis of the insecticide content of target insects. Unfortunately, this is very difficult because of biological contaminants and because of the rapid metabolism of most insecticides in insects. Field and laboratory research with Dursban and Thiodan have, however, been carried out. The laboratory research showed that the toxicity of an insecticide appears to be independent of the physical state of the insecticide prior to delivery to the target insect. Thus, the LD_{50} of these insecticides is substantially independent of whether they are delivered to target insects by (1) airborne-size droplets, (2) single lambda-size droplets, or (3) vapor. In effect, then, insect control can only be achieved when a lethal dose is actually delivered to the target insect. Our insect control failures are caused by our delivery system failures (Himel and Uk 1972a, 1972b).

In the field, the more concentrated the spray cloud, the farther downwind it will retain biological effectiveness. Typical data (table 3) were obtained when spray clouds of various concentrations of Dursban were tested against caged houseflies. The mortality of the flies is directly related to their Dursban content (up to 100 percent mortality) and the distance downwind for 100 percent mortality is directly related to Dursban concentration in the initial spray.

We believe that these data are an explanation of why the typical, inefficient sprays used with ULV sprays and undiluted insecticides are successful in the control of insects. We also believe that these data show one method for minimizing the biological effects of downwind drift, by limiting the concentration of insecticides in the initial spray.

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Table 3. The effects of spray concentration of Dursban¹ on the delivery of insecticide to caged houseflies² placed downwind; maximum droplet diameter 15 microns.

Distance (ft)	Effects of Dursban spray concentrations of ...					
	1 lb/gal		2 lb/gal		4 lb/gal	
	Mortality	Mean Dursban content ³	Mortality	Mean Dursban content	Mortality	Mean Dursban content
	<i>Percent</i>	<i>ng/fly</i>	<i>Percent</i>	<i>ng/fly</i>	<i>Percent</i>	<i>ng/fly</i>
100	-	-	100	364	100	214
250	42	17	100	270	100	339
500	52	20	14	25	100	115
750	0	10	63	27	100	51
1000	0	6	0	11	100	59
Controls	0		0		0	

¹Flow rate: 32 oz/min, 5 mph transport, 2 min; spray formulated with DOP and benzene.

²Two replications of 25 flies per cage were used; one replication was preserved for gas chromatographic analysis, the other was transferred to clean containers within 15 min following dispersal.

³In the laboratory the LD₅₀ for Dursban was determined to be 40 ng/fly.

Workshop Summary

John A. Neisess¹

The participants in the workshop were concerned with a wide range of spray deposit assessment problems that vary according to type of pesticide application. The objectives of an assessment method for a researcher are necessarily different from those for an operational program. Similarly, the requirements of application for forest or agricultural purposes, or mosquito control, etc., vary widely. Therefore, it would be very difficult to come up with a nice, neat standardized method suitable for all.

Very generally stated the goal of an assessment method for research is to provide the identification and maximization of the variables needed to obtain an effective control program. This method should be simple and ecologically safe. The assessment technique is therefore a research tool for obtaining basic knowledge which will eventually lead to increased target mortality resulting from more efficient application.

The specific assessment parameters that interest researchers relate to the bioassay, that is, correlating deposit with mortality. They are interested in how much toxic material is in the environment and to what degree this material is reaching the target. There was much discussion in our workshop on droplet size and size variation. The researchers want and need to know the droplet sizes that most effectively impact on the target, and what part of the spray-drop-size spectrum this effective droplet represents. The ultimate assessment method would provide the researcher with information on factors that produce droplets of the desired size. The assessment method may not disclose the mechanism by which impaction occurs, but it can reveal the effects of such things as meteorological conditions, site, and application technique on the deposition of the spray droplets.

The principles behind operational programs dictate different assessment requirements. People dealing with operational programs must

be able to assess the adequacy of the spray coverage resulting from the aerial application of the insecticide, for the enforcement of the application contracts. The assessment method has to be fast and simple so that the field man can request respraying in areas of uneffective coverage. The people in research should have predetermined what parameters will determine effective coverage.

People in the field want an assessment method that evaluates how much material reaches a sampling surface, such as a white card. The actual evaluation may be in terms of drop sizes, density of drops, volume of toxic material, or combinations thereof. It is imperative that the method be simple and inexpensive because the field people do not have the time or facilities to perform precise analysis.

Operational personnel are also interested in residues, and the possible contamination of forage crops and waterways from toxic chemicals applied to nearby areas. Work on this problem is usually conducted in conjunction with fisheries and wildlife departments. Therefore, it is desirable to have an assessment method that evaluates the spray drift.

Various assessment methods currently being used by participants in the workshop were discussed with respect to measurement of spray coverage. A. P. Randall, of the Chemical Control Research Institute, Ottawa, Canada, gave a short report on the type of assessment methods used in Canada for the last 20 years. They dye their formulations with soluble dyes and collect the spray deposit on glass plates and white Kromekote cards. The spray deposit is sampled in the open, for they have found that the deposit sampled in the open correlated very well with the deposit found in the trees. They have also found that the drop counts on the white cards gave a better correlation with insect mortality than the volume of spray removed from the glass plates.

The limitations of such an assessment method are the inability to count accurately the very small droplets in the 0-25 micron range, and the fact that a card or glass slide does not very well approximate the geometry of an insect. That is, this method

¹Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon.

does not allow for assessing the amount of toxic material or size of droplet actually delivered to the insect or its natural environment. The inability to assess the small droplets may be very important in view of the discussion of small droplets in this workshop. If the small droplet is the most effective size of drop for impacting on the insect, as reported by Dr. Himel, then the ultimate assessment method should evaluate this droplet size. Otherwise, we are not analyzing the part of the drop-size-spectrum that is of most interest to the researcher.

Soluble fluorescent tracers have been used as a tracer system to evaluate spray deposits. The deposit can be sampled with various artificial surfaces--white cards, aluminum plates, Mylar etc. Also, the fluorescent tracer can be removed from the foliage to give an estimate of the amount of toxic material reaching the insect's environment. Although the method is fast, inexpensive and sensitive, there are some problems. The fluorescent dyes fade when exposed to sunlight, and there are natural fluorescing contaminants which might complicate the assessment for the foliage samples. Because the drops on the white cards are manually sized and counted, the very small droplets cannot be accurately counted. The soluble tracer also does not provide a method for determining the amount of toxic material reaching the insect.

Automatic counting devices are available which count the spray drops collected on white cards. One such method is used at the Deseret Test Center. Photographs are made of the white cards, and the negatives are automatically scanned, and the drops sized and counted. The spread factor of the spray formulation is included in the calculation of the drop sizes. It was reported to the workshop that limitations in the photographic step restrict this method to the measurement of drops greater than 40 microns in diameter.

Dr. Himel described the use of gas-liquid chromatography (GLC) and mass spectroscopy as research methods for deposit assessment. Both of these instrumental methods have been used in the past for the direct chemical analysis of the actual pesticide. Dr. Himel described the use of tracer systems for evaluating the spray. These chemical tracers have the advantage of being fade resistant, and there are little or no contamination problems. However, this method can only evaluate the total volume of the spray deposited on some sampling surface. There is no provision for determining the number of droplets or droplet sizes.

The use of Rotor Rod Samplers was mentioned by Jack Barry in his paper dealing with the

Zectran dry liquid test. These samplers, again, sample only the total spray. This method does not give the delineation of the drop-size spectrum.

Anderson Sieve Samplers are another device used to sample the content of spray in volumes of air. By changing the size of sieves and the volume of air sucked into the sampling devices, specific drop-size ranges can be sampled by using a number of samplers together. It is possible to evaluate the entire spectrum of drops in a spray cloud with respect to particle size and cumulative percent of the spray in specific drop-size ranges. The only shortcomings of such a device are its expense and the need for a power supply--both of which would seem to limit the usefulness of the sampler in the field.

The only assessment method discussed in our session that provided a measure of the amount of pesticides and the size of spray droplets that was delivered to a target in its natural environment was the fluorescent-particle tracer method discussed by Dr. Himel. However, this method is a research tool only. The difficulty in handling the FP's and their cost make this method impractical for large-scale field use.

As for assessment methods currently used for operational programs, the most familiar is probably the oil-sensitive card used for years on the DDT programs. This method was adequate for enforcing contracts, but such methods have been shown to be unreliable for obtaining satisfactory correlation between the deposit and insect mortality.

Another assessment method, reportedly used with mosquito control, is the use of caged insects as an indicator of the amount of deposit. If the insects in the cages are dead, the overall coverage has presumably been adequate to obtain mortality.

A few new methods of assessment were discussed for use in research. A new sampling surface that better depicts the geometry of the insect was discussed. Ultimately this surface could be part of an analytical assessment method instead of a manual counting method. Such a surface could be washed, which would at least reveal the volume of spray impacting on a pseudo-insect, if not the actual drop size. Atomic absorption could be used to detect metallic salt tracers such as magnesium sulfate. These tracers would have the advantage that they do not fade. However, there might be contamination problems from naturally occurring salts. Electron spin resonance (ESR) was also suggested as an analytic tool for consideration. Nitroxides were reported as good tracers to be used with ESR.

A new method that might be applicable for operational use is the flying spot scanner, such as that used at the Deseret Test Center. The method provides for a visual estimate of the deposit on the card for enforcement of applicator contracts, but it is also sensitive enough to determine the specific parameters of drop size and the relative numbers of each size drop within the complete drop-

size spectrum, thus providing concise information about the extent of spray coverage.

In conclusion, if the workshop did not result in anything else, it made the participants aware of each other's problems. Alternate assessment methods, new professional contacts, or whole new concepts may have been initiated as a result of the workshop.

Discussion

DR. AKESSON: Just a quick comment, John. I feel that you are mixing the research instrumentation and the field instrumentation; you brought out both at various times, and you never separated them. May I suggest that we had better make a distinct separation, because if we do not we are going to confuse, confound, and frustrate the field people, especially when we refer to such things as scanning electron microscopes, atomic absorption spectrophotometers, and radiance trim, etc. So, if we are to continue in the future, the researchers should attempt to separate these two areas because of the differences. The field personnel frequently use indices, and tracers, where in research we attempt to deal with absolute values.

DR. NEISESS: Right, Norm, I tried to make that clear.

MR. BOYLE: I would like to clear up one point of possible confusion on automated droplet counting equipment. The Dugway machine can be set to count droplets as small as those falling between zero and 20 microns. The problem is that the process is photographic; what shows on the photograph is counted as a drop, and dust can pose problems in that size range. In practice, with droplets below 40 microns, the operator has to use optical magnification and count by eye to insure it is droplet stains that are being counted.

One other comment seems in order. Last year when the Missoula group brought their equipment to Dugway, we asked for only two changes in their standard operational procedures. The first concerned large drops, not small; overlapping droplet stains cannot be counted, and so we flew the aircraft high enough above the ground to minimize overlap of the large drops. The second was to fly crosswind instead of into the wind, and this too was intended to

provide an estimate of the decrease in average droplet separation and additionally to provide an estimate of the decrease in average droplet size as the downwind distance increased. Neither change complicates the analysis. If the droplet cloud is thought of as a stretched-out cone with the ground as its base and the aircraft at the vertex, you can easily pass a new plane closer to the aircraft, in effect, put the ground where you want it, and the process is interpolative, not extrapolative.

We tested the C-47 system over a sampling array covering several square miles, and with complete meteorological instrumentation. The Dugway droplet spectrum data, contamination density estimates, and swath widths matched what Missoula had already determined on a much less expensive program. We increased the sample size tremendously but I do not think we added much new information to the spray system characterization.

DR. PIEPER: I was in the assessment workshop also and I thought there was an interesting suggestion offered that was not mentioned here. That was the addition of spores of *Bacillus globigii* to the spray formulation. I thought this suggestion could be used by a great many people and it does not require expensive equipment.

DR. MAKSYMUK: I believe, John, that you mentioned that there was a minimum sensitivity on Kromekote cards using fluorescent tracers of a spherical drop size of 20 microns. Our published research shows that we can go down to 7 microns as far as spherical drop size is concerned. But the spot size on the card is around 20 microns. Now we do have simplified and accepted field methods for rapid determination of atomization based on the D-max method that I published in an article that is being, or was being used routinely over a number of years. As far as estimating gallons

per acre in a forest using oil-sensitive red cards and no dye in the sprays, or oil sprays, Isler and Davis at the Beltsville Laboratories developed this method, following some Canadian input by Elliot, and it was used operationally for years. It is very rapid and insensitive but it gives you go or no-go information and this is probably enough for the control operations and it takes minimum time to compare the standards to the cards in the forest and to estimate the coverage.

MR. FURLOW: I would like to ask your group a question with respect to the determination of aerosol droplet sizes of ULV sprays, and the evaluation of the equipment and the use of these sprays on a day-to-day basis in the field. What is the current problem on using any convenient technique that gives consistent comparable results from one nonthermal fogger to another, to get results that are known to be significantly different from the true volume mean diameter, and do not truly reflect the size of the particles that are actually more effective in reaching and killing the insect?

DR. AKESSON: May I suggest, John, that this is precisely what I was referring to. You are using an index because you are not obtaining an add-value for the drop size. The part that hurts is when someone uses a field technique and does not describe what he did or the relation between this as an index and the add-value. Then this gets into the literature as add-values, and it can really confuse things.

But if you do this, and acknowledge what you are doing, I see nothing wrong at all, because these are field techniques which are highly essential.

MR. FURLOW: Is that the consensus of your committee or group?

MR. RANDALL: There is one point I would like to bring out in regard to this method of using cards. That is, no one has mentioned standardizing the cards in terms of the spread factor. Now the solution you use will depend on the size of the drops in the cards, and you have a variation of a spread factor of 2 to 6. So that one material will have spread factor of 2 and others may have one of 6. The drop size may be identical with the same kinds of materials; therefore, you cannot compare these two together because they will not have the same spread factor at all.

MR. CHATIGNY: Responding to the particle size question, I think that the size you measure is directly dependent on the instrument you use to measure. There are a variety of instruments. However, there are obviously some methods that are standardized and some of these not found in the literature or connected with the disciplines of the scientists present here. Dr. Dimmick informs me that this came up in their session, and he will amplify this in his summary presentation.

Rapporteur Summary

Mark A. Chatigny

This workshop has covered a very broad spectrum of problems. Solutions for some are well in hand, others are emergent in new areas; all appear to have some intereffect. We have considered meteorological physics, water surface dispersion, leaf coverage, and the chemistry, toxicity and degradation of pesticides. The need for close control of aerosol output, formulation, and particle size to control hazards to the target and nontarget populations (if you will define as "nontarget" those organisms we do not wish to affect) has been discussed. Certainly the human and animal population and the environment have been endangered to some degree by some of the early pesticide applications. We have pointed out that there is a need for improved dose-response data from our insecticide applications, and these, of course, are going to vary as widely as the number of insecticides being used and the range of target species. There is also need for additional work on dispersal techniques.

All things considered, we have a need for a coordinated, multidisciplinary program. We have entomologists, physicists, biologists, engineers and meteorologists, each group with its own idiom. Basically they work in "English" (though I am not always sure of that) but it is apparent that some of the working groups spent a great deal of their time just getting their words to mean the same things or to arrive at some common usage during the course of their sessions. This is a problem, because if you belong to an entomological society, you are not usually going to be talking to microbiologists. If you attend engineering or civil engineering society meetings, you are probably not going to be talking to many agricultural engineers. Dr. Akesson pointed out that he obtains information from the mechanical engineers and the civil engineers "rather laboriously." There is a strong need for interdisciplinary communication. We find, for example, that some of the early characterization of spray-nozzle work was done by Japanese workers who were interested in spraying coal slurries for efficient burning. The spray parameters are the same, and the particle-size distribution from single and double fluid nozzles prevailed for them just as it does for us. What this amount to--and I think Dr. Cramer pointed this out quite clearly--is that we are in need of a systems approach to our composite problems. It is essential for us to get together as often as we can, to share language, share approaches, and make a systematic coordination of our efforts in both the field and laboratory.

In this meeting we have also seen quite a gap in communications between researchers and the people in the field. Practical considerations limit the field people (in determining particle size) to such practices as putting out settling cards and saying, "That tells me right now what was put on, where it went and that the contract I had with a pest control operator to put out materials has been fulfilled." As researchers we might say, "Well, that does not tell you what is the effective fraction of the material applied." He might like to know the particle size, the concentration of pesticide in each particle, and the micro- and macro-meteorological conditions that affected these things. The control operator, although interested, must respond "I can't find out all that stuff; I just want to know, did it get there and did the contract get fulfilled." It is apparent that a systems approach, with measurement of many parameters, may be necessary.

We in research are going to ask the man in the field to get some information for us. We are going to have to get that information fed back into research and higher technology areas and use it in our system model, and in turn, give the operator some direct answers that will help him then and there. We are a long way from that, but we have some of the tools at hand.

Surprisingly enough we have more tools at hand than many of us are aware of. For example, Dr. Mort Rothenberg (Deseret Test Center) has some 30 years of experience in aerosol travel, chemical particle deposition rates, and micro- and macrometeorological effects under just about every conceivable condition. Much of it is tabulated and computerized and there is a veritable mountain of information available. We are not making adequate use of it; I can tell that from the conversations here. Some of the problems of particle physics described in this meeting were described some 25 years ago, when a great deal of that data such as that compiled by Dr. Rothenberg's group was being assembled. There have been offhand references to the work of Latta, Hochberg, LaMer, and others; many of these people who worked in the Office of Scientific Research and Development in the 1940's formulated many of the basic equations and principles on which a lot of dispersion models were built. The work needs updating, but more than that, it needs to be made available to this community--that is, to the people doing research, and (in usable form) to pest control operators.

I venture to say that our problems in application are going to get worse before they get any better. We are going to have increased pressure by the ecologists for minimal contamination of the biosphere. We are going to have decreased interest in development of new formulations by the chemical companies. It costs a great deal to develop a new chemical to be dispensed in small fractions of a pound instead of hundreds of pounds per acre and to meet stringent standards for nontoxicity and degradability. The manufacturers' incentives are certainly being decreased. Some of the manufacturers may want to take issue with me on that, but for our purposes it is not too far from the mark. We are probably moving toward more small-particle sprays. Much of the discussion centered around approximately 20 microns as the optimal particle size. Well, let us use that for the moment, with the reservation that we may, as Dr. Himel has suggested, want to put out a larger particle size with an equivalent amount of toxic material in order to control coverage on the target. We can formulate that way, but the trend may be toward the small particle size.

As Dr. Dimmick has pointed out, when we do that, we are getting into the respirable particle size range. Further, when we get into small-particle generation, we have the inevitable generation of a lot of very small particles. Now the very small particle (this may mean 0.5 to 0.8 microns and smaller) gets very deep into the respiratory system of the human or animal and is retained and adsorbed rapidly. When you produce an aerosol of a few million per cubic meter of 20-micron particles, you also produce 100 million or so per cubic meter in the 0.5 to 8 micron range. We have not had simple systems for measuring these particle sizes. If these are persistent pesticides, or in a carrier that is persistent, they are going to stay in the respiratory system or some other part of the human body, where they may, in fact, be concentrated. Many people are going to be asking, "What kind of hazard are these pest control operators giving us now?" And you will have to bear with them because they have a valid concern. While all this is going on, our legislators will be responding to public pressures and (although I do not want to criticize the legislators, who are "vox populi") they will sometimes respond in a manner that does not reflect the state of the art in control technology. They will simply say, "Do it!"--that is, "eliminate this hazard"--and we may not be prepared to "do it" at that time without undue loss or cost. There are no simple answers to these

complex problems that I can see defined in these meetings. I think we have given it a very good try and have made good progress in defining our problem areas.

Some directions are indicated. Certainly the voluntary communications, like this workshop, work very well. I think you will all agree that this has been a good and successful meeting. Also, I think we could establish research programs that are more closely tied to applications. On the other hand, the applications people need to come back to the researcher with some data and some indication of practical limitations. We may sit in the ivory tower and cook up a lovely particle-size analyzer that will work in the laboratory (and we need that), but it may be a harder task to get a simple piece of machinery to the man in the field so that he can give us back one or two parameters that can be fitted into our model at a given quantity and particle size, and what is the effective dose in the target area. I think we are not too far from this capability if we use the resources available to us.

Another suggested aim is perhaps more immediately attainable--that is to establish an ad hoc or *pro tem* standardization of working group. It certainly must be intersociety, interagency, interdisciplinary--or whatever the desired term--to cross the many disciplines represented here. We may need entry to several government agencies for this, and it has been suggested to Dr. Schirley that we go to the Federal Working Group on Pest Management for sanction and assistance. He has agreed that this is a reasonable thing. Perhaps he can speak on this working group to Environmental Protection Agency and Food and Drug Administration and other cognizant organizations. This is fine. He has suggested that he would be willing to go to the National Science Foundation and help us get some funding for a maintained working group. Dr. Rothenberg, who is on the committee of the National Science Foundation and the Research Applied to National Needs committee, said that he would support such a request. We should not underestimate the need for such a group or the complexity of their work.

I have had some personal experience in standardization of aerosol procedures. Our laboratory participated in a tripartite working group (The United Kingdom, Canada, and the United States) on aerosols; it functioned for about 8 years. A great part of that time was spent in standardizing aerosols, equipment, procedures, samplers, etc., so that we could

all so (simultaneously) at least one kind of experiment, or field test, in which the data would be directly comparable among all participants. One of the more elementary things that became a real problem was that the temperature of one of the aerosol chambers varied by about half a degree Centigrade from those in other installations. The data received from this unit differed considerably from that received from the others. Attention to exact details of every aspect of the equipment and work was essential for good control of the experiments.

Synopsis of Comments from Evening Dinner Session

At the dinner meeting following the first day of the workshop, participants were requested to submit comments and questions. These were summarized by the Coordinating Committee.

Several people indicated interest in holding the workshop annually; one person felt that it did not have the scope or "punch" for

an annual affair. At least two persons said (1) the workshop should be extended another day, (2) the individual workshops were too short, and (3) the workshop should not be so large, as the number of people and lack of time limited the discussion. One person felt that the chairman of the assessment group was too constrictive. Another thought that one single theme, rather than three, would be more productive.

Some general comments and suggestions were made. It was felt that (1) a definition of target and nontarget populations is needed; (2) too much time was devoted to drop spectrum and deposition analysis when there was no standard or basic formulation as a means of comparison; (3) a technique is needed to disseminate monodispersed aerosols; (4) the impaction efficiency of setae on spruce budworm should be investigated and environmental contamination from an assessment standpoint should be considered; and (5) a good reliable method for analyzing droplets or particles below 20 microns is needed.

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